Electromagnetism Extra Study Questions

Short Answer

1. The electrostatic force between two small charged objects is 5.0×10^{-5} N. What effect would each of the following changes have on the magnitude of this force, considered separately?
   (a) The distance between the charges is doubled.
   (b) The charge on one object is tripled, while the charge on the other is halved.
   (c) Both of the above changes occur simultaneously.
2. What is the force of repulsion between two small spheres 1.0 m apart, if each has a charge of 1.0×10^{-12} C?
3. Two charged spheres 10 cm apart attract each other with a force of 3.0×10^{-6} N. What force results from each of the following changes, considered separately?
   (a) Both charges are doubled and the distance remains the same.
   (b) An uncharged, identical sphere is touched to one of the spheres, and then taken far away.
   (c) The separation is increased to 30 cm.
4. The force of electrostatic repulsion between two small positively charged objects, A and B, is 3.6×10^{-5} N when AB = 0.12 m. What is the force of repulsion if AB is increased to the following?
   (a) 0.24 m
   (b) 0.30 m
   (c) 0.36 m
5. Calculate the force between charges of 5.0×10^{-8} C and 1.0×10^{-7} C if they are 5.0 cm apart.
6. What is the magnitude of the force a 1.5×10^{-6} C charge exerts on a 3.2×10^{-4} C charge located 1.5 m away?
7. Two charged spheres; 4.0 cm apart, attract each other with a force of 1.2×10^{-9} N. Determine the magnitude of the charge on each, if one has twice the charge (of the opposite sign) as the other.
8. Two equal charges of magnitude 1.1×10^{-7} C experience an electrostatic force of 4.2×10^{-4} N. How far apart are the centres of the two charges?
9. What is the electric field intensity 0.50 m away from a small sphere with a positive charge of 1.6×10^{-8} C?
10. A negative charge of 2.4×10^{-6} C experiences an electric force of magnitude 3.2 N, acting to the left. What is the magnitude and direction of the electric field at that point?
11. At a certain point in an electric field, the magnitude of the electric field intensity is 12 N/C. Calculate the magnitude of the electric force exerted on a point charge of 2.5×10^{-7} C, located at this point in the field.
12. What is the magnitude and direction of the electric field intensity at a point 3.0 m to the right of a positive point charge of 5.4×10^{-4} C?
13. The electric field strength midway between a pair of oppositely charged parallel plates is 3.0×10^{3} N/C. What is the electric field intensity halfway between this point and the positively charged plate?
14. Calculate the electric potential a distance of 0.40 m from a spherical point charge of $+6.4 \times 10^{-6}$ C. (Take $V = 0$, at infinity.)
15. How much work must be done to increase the potential of a charge of 3.0×10^{-7} C by 120 V?
16. In a uniform electric field, the potential-difference between two points 10 cm apart is 80 V. Calculate the magnitude of the electric field intensity.

17. The electric field intensity in the region between two parallel plates is 400 N/C. If the plates are connected to a battery with a potential difference of 90 V, what is the separation of the plates?

18. The potential at a distance of 25 cm from a point charge is -6.4×10^4 V. What is the sign and magnitude of the point charge?

19. It takes 4.2×10^{-3} J of work to move 1.2×10^{-6} C of charge from point X to point Y in an electric field. What is the potential difference between X and Y?

20. Calculate the magnitude of the electric field in a parallel plate apparatus whose plates are 5.0 mm apart and have a potential difference of 300 V between them.

21. What potential difference would have to be maintained across the plates of a parallel plate apparatus, if they are 1.2 cm apart, to create an electric field of intensity 1.5×10^4 N/C?

22. Calculate the charge on a small sphere with an excess of 5.0×10^{14} electrons.

23. In a Millikan type experiment, two horizontal plates are 2.5 cm apart. A latex sphere of mass 1.5×10^{-15} kg remains stationary when the potential difference between the plates is 460 V, with the upper plate positive.
(a) Is the sphere charged negatively or positively?
(b) What is the magnitude of the electric field intensity between the plates?
(c) Calculate the magnitude of the charge on the latex sphere.
(d) How many excess or deficit electrons does the sphere have?

24. How many electrons must be removed from a neutral, isolated conducting sphere to give it a positive charge of 8.0×10^{-8} C?

25. What will be the force of electric repulsion between two small spheres placed 1.0 m apart, if each has a deficit of 10^8 electrons?

26. The potential difference between two parallel plates is 1.5×10^2 V. If 0.24 J of work is required to move a small charge from one plate to the other, what is the magnitude of the charge?

27. An alpha particle has a positive charge of $2e$ and a mass of 6.6×10^{-27} kg. With what velocity would an alpha particle reach the negative plate of a parallel plate apparatus with a potential difference of 2.0×10^3 V, if it started, at rest
(a) next to the positive plate
(b) at the midpoint between the plates

28. A pith ball of mass 1.0×10^{-5} kg with a positive charge of 4.0×10^{-7} C is slowly pulled by a string a distance of 50 cm through a potential difference of 8.0×10^2 V. It is then released from rest and "falls" back to its original position. Calculate the following:
(a) the work done by the string in moving the pith ball
(b) the average force required to do this work
(c) the kinetic energy with which the pith ball reaches its original position
(d) its speed just as it reaches its original position

29. What potential difference is required to accelerate a deuteron, of mass 3.3×10^{-27} kg and charge 1.6×10^{-19} C, from rest to a speed of 5.0×10^6 m/s?

30. Two small, oppositely charged spheres have a force of electric attraction between them of 1.6×10^{-2} N. What does this force become if each sphere is touched with its identical, neutral mate, and then replaced twice as far apart as before? The mates are taken far away.

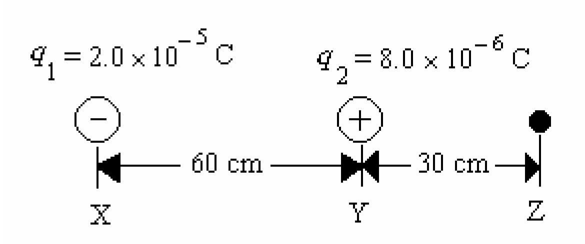
31. What is the distance between two protons ($e = +1.6 \times 10^{-19}$ C) when they exert forces on each other of magnitude 4.0×10^{-11} N?

32. Assume that a single, isolated electron is fixed at ground level. How far above it, vertically, would another electron have to be, so that its mass would be supported by the force of electrostatic repulsion between them? (mass of electron = 9.1×10^{-31} kg)

33. A small test charge of +1.0 μC experiences an electric force of 6.0×10^{-6} N to the right.
(a) What is the electric field intensity at that point?
(b) What force would be exerted on a charge of -7.2×10^{-4} located at the same point, in place of the test charge?

34. What is the magnitude and direction of the electric field 1.5 m to the right of a positive point charge of magnitude 8.0×10^{-3} C?

35. What is the magnitude and direction of the electric field at point Z in the diagram below?



36. The electric field intensity at a point between two large parallel plates is 4.8×10^{2} N/C. What does the electric field become, as a result of each of the following changes, considered separately (the plates are isolated),
(a) when the distance between the plates is halved
(b) when the amount of charge on each plate is tripled
(c) when the plates are connected together by a conducting wire

37. Calculate the electric potential 0.50 m from a 4.5×10^{-4} C point charge.

38. How much energy is acquired by an electron, whose charge is 1.6×10^{-19} C, in moving through a potential difference of 2.5×10^{4} V?

39. How much work must be done to bring two protons from an infinite distance apart to within 1.0×10^{-15} m of each other? (This shows why particle accelerators are needed!)

40. What is the electric field intensity between two large parallel plates 2.0 cm apart, if a potential difference of 450 V is maintained between them?

41. What potential difference applied between two parallel plates will produce an electric field strength of 2.5×10^{3} N/C, if the plates are 8.0 cm apart?

42. How far apart are two parallel plates if a potential difference of 600 V produces an electric field intensity of 1.2×10^{4} N/C between them?

43. To neutralize an electroscope with a charge of $+8.0 \times 10^{-12}$ C, how many electrons must be added to it?

44. An electron is released from rest adjacent to the negative plate in a parallel plate apparatus. A potential difference of 500 V is maintained between the plates, and they are in a vacuum. With what speed does the electron collide with the positive plate?

45. What potential difference would accelerate a helium nucleus from rest to a kinetic energy of 1.9×10^{-15} J? ($q = +2e$, for a helium nucleus)

46. A straight conductor carries a current of 15 A through a magnetic field a distance of 10 cm, when the magnetic field intensity is 0.60 T. Calculate the magnitude of the force on the conductor, when the angle between it and the magnetic field is
(a) 90°
(b) 45°
(c) 0°

47. A wire in the armature of an electric motor is 25 cm long and remains in, and perpendicular to, a uniform magnetic field of 0.20 T. What force is exerted on the wire when it carries a current of 15 A?

48. What length of conductor, running at right angles to a 0.033 T magnetic field and carrying a current of 20 A, experiences a force of 0.10 N?

49. A wire connecting a taillight to a motorcycle battery is 1.0 m long, and is lying perpendicular to the Earth's magnetic field. If it experiences a force of 6.0×10^{-5} N when carrying a current of 1.5 A, what is the magnitude of Earth's magnetic field at that location?

50. Two electrical line poles are situated 50 m apart, one directly north of the other, and the horizontal wire running between them carries a DC current of 200 A. If Earth's magnetic field, in the vicinity, has a magnitude of 5.0×10^{-5} T and the magnetic inclination is 45°, what is the magnetic force on the wire?

51. Determine the magnitude and direction of the magnetic force on a proton moving horizontally to the north at 8.6×10^{4} m/s, as it enters a magnetic field of 1.2 T, pointing vertically upward.

52. What is the magnitude and direction of a magnetic field if an electron moving through it at 2.0×10^{6} m/s experiences a maximum magnetic force of 5.1×10^{-14} N [left] when moving vertically straight up?

53. Calculate the radius of the path taken by an alpha particle (He^{++} ion, of charge 3.2×10^{-19} C and mass 6.7×10^{-27} kg) injected at a speed of 1.5×10^{7} m/s into a uniform magnetic field of 2.4 T, at right angles to the field.

54. An airplane flying through Earth's magnetic field at a speed of 200 m/s acquires a charge of 100 C. What is the maximum magnetic force on it in a region where the magnitude of Earth's magnetic field is 5.0×10^{-5} T?

55. What is the strength of the magnetic field 15 cm from a long, straight conductor carrying a current of 100 A?

56. What is the magnetic field strength 20 cm from a long, straight conductor with a current of 60 A flowing through it?

57. What current is flowing through a straight wire if the magnetic field strength 10 cm from the wire is 2.4×10^{-5} T?

58. At what distance from a straight conductor, with a current of 200 A flowing through it, is the magnetic field intensity 8.0×10^{-4} T?

59. What is the magnetic field strength at a point midway between two long, parallel wires, 1.0 m apart, carrying currents of 10 A and 20 A, respectively, if the currents are (a) in opposite directions and (b) in the same direction?

60. A long, solid, copper rod has a circular cross-section of diameter 10 cm. It carries a current of 1000 A, uniformly distributed across its area. Calculate the magnetic field strength at these four positions below.
(a) at the centre of the rod
(b) 2.5 cm from the centre
(c) 5.0 cm from the centre
(d) 7.5 cm from the centre

Hint: Remember, the current in Ampère's Law is the current flowing through the area enclosed by the chosen path.

61. What is the magnetic field strength in the core of a solenoid 5.0 cm long, with 300 turns and a current of 10 A?

62. 14-gauge copper wire can safely carry a current of 12 A. How many turns must be wound on a coil 15 cm long in order to produce a magnetic field of strength 5.0×10^{-2} T?

63. What is the magnetic field strength in the core of a coil 10 cm long, with 420 turns and a current of 6.0 A?

64. A coil 8.0 cm long is composed of 400 turns of wire, and produces a magnetic field of strength 1.4×10^{-2} T in its core. What is the current flowing through the coil?

65. What is the force between two parallel conductors 2.0 m long, carrying currents of 4.0 A and 10.0 A, that are 25 cm apart in a vacuum?

66. Calculate the force per unit length between two parallel conductors, each carrying a current of 8.0 A, if they are 1.0 cm apart.

67. What is the maximum equal current in each of two parallel conductors 5.0 m long and 12 cm apart, if the force between them must not exceed 2.0×10^{-2} N?

68. How far from a wire carrying a current of 5.0 A is a second, parallel wire with a current of 10 A, if the force per unit length between them is 3.6×10^{-4} N/m?

69. Calculate the force per metre pushing the two wires in an extension cord apart when 1.0 A of DC current flows, to light a 100 W study lamp. The separation of the wires is 2.0 mm and the insulation behaves like a vacuum.

70. A 15 cm length of wire carrying a current of 20 A is situated at right angles to a uniform magnetic field. If it experiences a magnetic force of 0.40 N, what is the magnetic field intensity?

71. What is the magnetic force on a wire 0.25 m long, carrying a current of 4.0 A, when placed in a uniform magnetic field of 0.50 T, at an angle of 45° to the wire?

72. What is the magnitude and direction of the force on an electron moving horizontally to the west at 3.2×10^{6} m/s through a uniform magnetic field of 1.2 T pointing horizontally to the south?

73. An electron, shot at right angles into a uniform magnetic field of 2.0×10^{-3} T, experiences a deflecting force of 2.6×10^{-16} N. With what velocity is it moving?

74. What is the magnitude and direction of the magnetic field 20 cm to the east of a straight vertical wire carrying a current of 12 A downward through air?

75. What current in a straight wire produces a magnetic field no greater than 1.0×10^{-4} T, at a distance of 10 cm in air?

76. What is the magnetic field strength in the air-core of a solenoid 10 cm long, consisting of 1200 loops of wire carrying a current of 1.0 A?

77. What is the magnetic force between two parallel wires 50 m long and 10 cm apart, each carrying a current of 100 A in the same direction?

78. What is the charge-to-mass ratio for a particle accelerated to a velocity of 6.0×10^{6} m/s, that moves in a circular path of radius 1.8 cm perpendicular to a uniform magnetic field of 3.2×10^{-2} T?

79. A proton, of mass 1.67×10^{-27} kg, moves in a circle in the plane perpendicular to a uniform 1.8 T magnetic field. If its radius of curvature is 3.0 cm, what is its velocity?

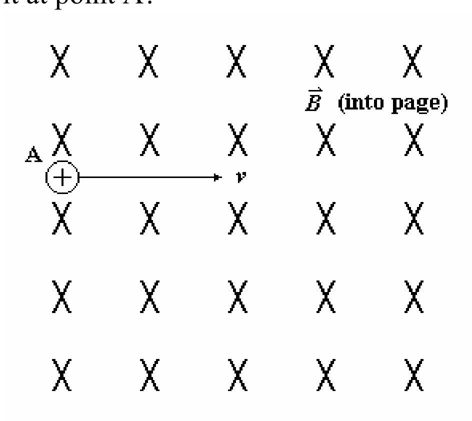
80. A singly ionized particle ($q = +e$) is moving at 1.9×10^4 m/s at right angles to a uniform magnetic field of 1.0×10^{-3} T. If the radius of curvature of its path is 0.40 m, what is its mass?

81. A singly ionized $^{235}_{92}U$ ion, of mass 3.9×10^{-25} kg, is accelerated through a potential difference of 1.0×10^5 V.
(a) What is its maximum velocity?
(b) What is the radius of the path it would take if injected at 90° into a 0.10 T uniform magnetic field at this velocity?

82. Calculate the quantity indicated for each of the following electromagnetic waves.
(a) the frequency of a 1.8 cm wavelength microwave
(b) the wavelength of a 3.2×10^{10} Hz radar signal
(c) the distance between adjacent maxima of magnetic field strength in the electromagnetic wave coming from a 60 Hz transmission line
(d) the frequency of red visible light, of wavelength 650 nm

83. An electron, with mass of 9.1×10^{-31} kg and charge of 1.6×10^{-19} C, is accelerated to a velocity of 4.0×10^6 m/s, then enters a uniform magnetic field of 5.0×10^{-3} T at an angle of 90° to the field.
(a) What is the radius of the circular path it follows?
(b) Through what potential difference was the electron accelerated?

84. A uniform magnetic field, of magnitude 0.25 T, consists of field lines pointing into the page, as indicated by x's (representing the tails of straight arrows moving away from the observer) in the sketch. A proton with a positive charge of 1.6×10^{-19} C enters this magnetic field at point A, moving with a horizontal velocity of 4.0×10^6 m/s [right], as shown below. What is the magnitude and direction of the instantaneous force exerted on it at point A?



85. Microwaves with a wavelength of 1.5 cm are used to transmit television signals coast to coast, using a network of relay towers.
(a) What is the frequency of these microwaves?
(b) How long would it take a TV signal to cross the continent from St. John's, Newfoundland, to Victoria, British Columbia—a distance of 8000 km?

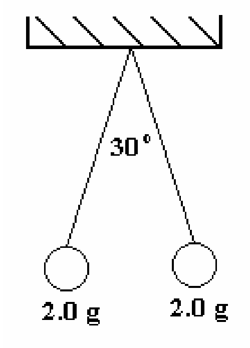
86. What is the frequency range for visible light whose wavelengths are between 400 nm and 750 nm?

87. Cosmic rays come from outer space and have a frequency of about 1×10^{26} Hz. What is their approximate wavelength?

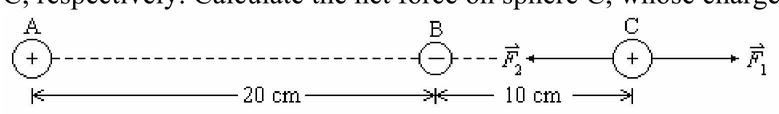
88. How many wavelengths of the radiation emitted by a 60 Hz transmission line would it take to span the North American continent, a distance of about 8.0×10^3 km?

Problem

89. Two identical, small spheres of mass 2.0 g are fastened to the ends of a 0.60 m long light, flexible, insulating fishline. The fishline is suspended by a hook in the ceiling at its exact centre. The spheres are each given an identical electric charge. They are in static equilibrium, with an angle of 30° between the string halves, as shown. Calculate the magnitude of the charge on each sphere.



90. Charged spheres A and B are fixed in position, as shown, and have charges of $+4.0 \times 10^{-6}$ C and -2.5×10^{-7} C, respectively. Calculate the net force on sphere C, whose charge is $+6.4 \times 10^{-6}$ C.



91. Three negatively charged spheres, each with a charge of 4.0×10^{-6} C, are fixed at the vertices of an equilateral triangle whose sides are 20 cm long. Calculate the magnitude and direction of the net electric force on each sphere.

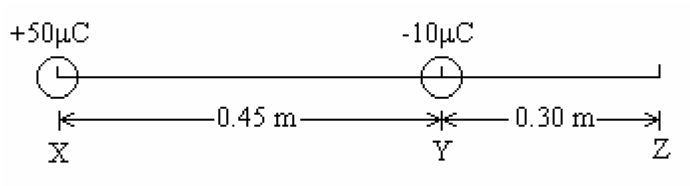
92. Three objects, carrying charges of -4.0×10^{-6} C, -6.0×10^{-6} C, and $+9.0 \times 10^{-6}$ C, respectively, are placed in a line, equally spaced from left to right by a distance of 0.50 m. Calculate the magnitude and direction of the net force acting on each that results from the presence of the other two.

93. Two small spheres, with charges 1.6×10^{-5} C and 6.4×10^{-5} C, are situated 2.0 m apart. They have the same sign. Where, relative to these two objects, should a third object be situated, of the opposite sign and whose charge is 3.0×10^{-6} C, so that it experiences no net electrical force? Do we really need to know the charge or sign of the third object?
(on the line joining them, 0.67 m from the 1.6×10^{-5} C charge)

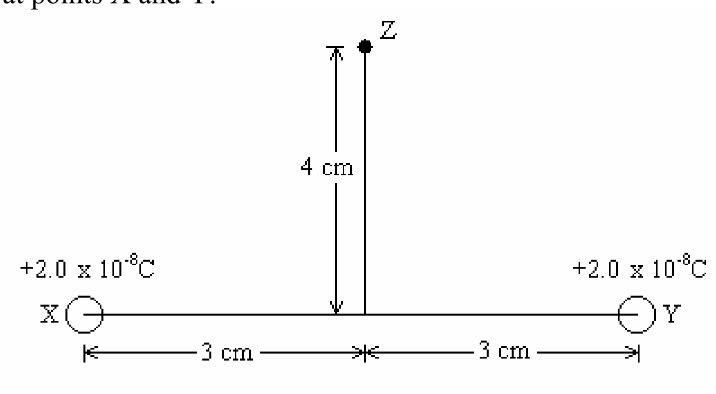
94. Calculate the electric field intensity midway between two negative charges of 3.2×10^{-9} C and 6.4×10^{-9} C that are 30 cm apart.

95. The electric field intensity between the plates of a parallel plate apparatus is 1.5×10^{2} N/C. What is the effect on the electric field intensity of each of the following changes, considered separately?
(a) The charge on each plate is doubled.
(b) The plates are moved three times as far apart.

96. What is the magnitude and direction of the electric field at point Z in the diagram below, due to the charged spheres at points X and Y?



97. Determine the magnitude and direction of the electric field at point Z in the diagram below, due to the charges at points X and Y.



98. A small object has an excess of 5.00×10^9 electrons. Calculate the magnitude of the electric field intensity and the electric potential at a distance of 0.500 m from the object.

99. Two large, horizontal metal plates are separated by 0.050 m. A small plastic sphere is suspended halfway between them, and experiences an electric force of 4.5×10^{-15} N that just balances the force of gravity on it.
(a) What is the potential difference between the plates, if the charge on the plastic sphere is 6.4×10^{-19} C?
(b) Calculate the mass of the plastic sphere.

100. An oil drop, whose mass is found to be 4.95×10^{-15} kg, is balanced between two large, horizontal parallel plates 1.0 cm apart, by a potential difference of 510 V, with the upper plate positive. What is the charge on the drop, both in coulombs and in elementary charges, and is it an excess or deficit of electrons?

101. Delicate measurements indicate that the Earth has an electric field surrounding it, similar to that around a positively charged sphere. Its magnitude at the surface of the Earth is about 100 N/C. What charge would an oil drop of mass 2.0×10^{-15} kg have to have, in order to remain suspended by the Earth's electric field? Give your answer in both coulombs and elementary charges.

102. A small pith ball of mass 1.0×10^{-5} kg and charge $+2.0 \times 10^{-9}$ C is at rest 25 cm from a fixed positive charge of 5.0×10^{-6} C. Neglecting gravitational effects and air resistance, with what speed will the pith ball be moving when it is 50 cm from the other charge?

103. Two electrons are held, at rest, 10^{-12} m apart, and then released. With what kinetic energy and speed is each moving when they are a "large" distance apart?

104. One model of the structure of the hydrogen atom consists of a stationary proton with an electron moving in a circular path around it, of radius 5.3×10^{-11} m. The masses of a proton and an electron are 1.67×10^{-27} kg and 9.1×10^{-31} kg, respectively.
(a) What is the electrostatic force between the electron and the proton?
(b) What is the gravitational force between them?
(c) Which force is mainly responsible for the electron's centripetal motion?
(d) Calculate the velocity and period of the electron's orbit around the proton.

105. Two small, identical, charged spheres attract each other with a force of 8.0×10^{-5} N, when they are 30 cm apart. They are touched together, and are again placed 30 cm apart, but they now exert a force of repulsion of 1.0×10^{-5} N on each other.
(a) What is the charge on each sphere after they are touched?
(b) What was the charge on each before they were touched?

106. Two small charges, $+4.0 \times 10^{-5}$ C and -1.8×10^{-5} C, are placed 24 cm apart. What is the force on a third small charge, of magnitude -2.5×10^{-6} C, if it is placed on the line joining the other two, and
(a) 12 cm to the outside of them, on the side of the negative one
(b) 12 cm to the outside of them, on the side of the positive one
(c) midway between them

107. A charge of 1.2×10^{-3} C is fixed at each corner of a rectangle that is 30 cm wide and 40 cm long. What is the magnitude and direction of the electric force on each charge? What is the electric field and the electric potential at the centre?

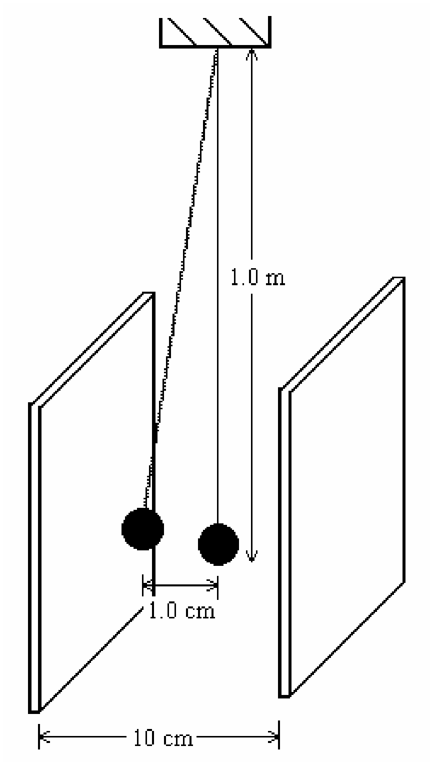
108. A 1.0×10^{-6} C test charge is 40 cm from a 3.2×10^{-3} C charged sphere. How much work was required to move it there from a point 100 cm away from the sphere?

109. An oil drop, of mass 2.6×10^{-15} kg, is suspended between two parallel plates 0.50 cm apart, and remains stationary when the potential difference between the plates is 270 V. What is the charge on the oil drop, and how many excess or deficit electrons does it have?

110. A metallic ping-pong ball, of mass 0.10 g, has a charge of 5.0×10^{-6} C. What potential difference, across a large parallel plate apparatus of separation 25 cm, would be required to keep the ball stationary?

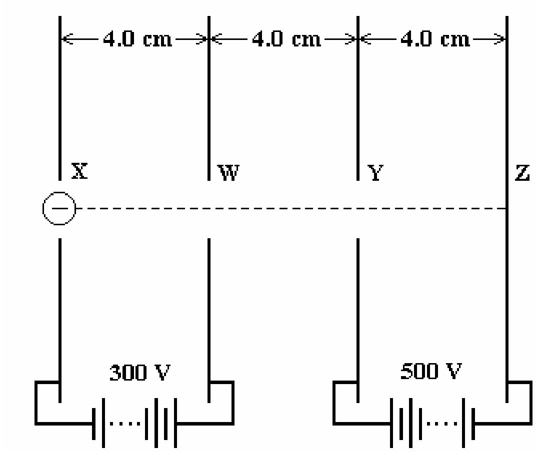
111. Determine the electric potential and electric field intensity at a point 0.40 m from a small sphere with an excess of 10^{12} electrons.

112. A ping-pong ball of mass 3.0×10^{-4} kg is hanging from a light thread 1.0 m long, between two vertical parallel plates 10 cm apart, as shown. When the potential difference across the plates is 420 V, the ball comes to equilibrium 1.0 cm to one side of its original position.
(a) What is the electric field intensity between the plates?
(b) What is the tension in the thread?
(c) What is the magnitude of the electric force deflecting the ball?
(d) What is the charge on the ball?



113. An electron with a velocity of 5.0×10^6 m/s is injected into a parallel plate apparatus through a hole in the positive plate. It moves across the vacuum between the plates, colliding with the negative plate at 1.0×10^6 m/s. What is the potential difference between the plates? (mass of electron = 9.1×10^{-31} kg)

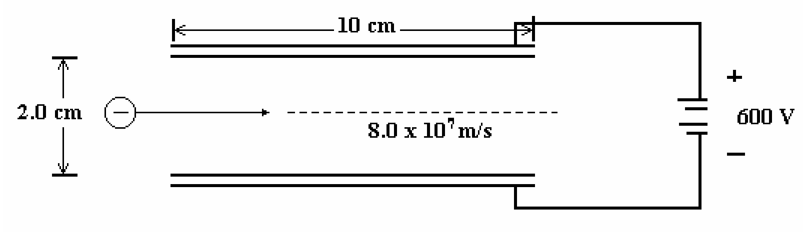
114. Four parallel plates are connected, in a vacuum, as shown:



An electron, essentially at rest, drifts into the hole in plate X and is accelerated to the right. Assuming that its vertical motion is negligible, it passes through hole W, goes on through hole Y, and then continues moving towards plate Z. Using the dimensions and potential differences given in the diagram, calculate the following.
(a) the velocity with which the electron passes through hole W
(b) the velocity with which it passes through hole Y
(c) the distance from plate Z of the point where the electron momentarily comes to rest
(d) the velocity with which it arrives back at plate X

115. Two alpha particles (mass = 6.6×10^{-27} kg, charge = 3.2×10^{-19} C), separated by an enormous distance, approach each other along a “head-on collision” path. Each has a speed of 3.0×10^{6} m/s to begin with. Calculate their minimum separation, assuming no deflection from their original path.

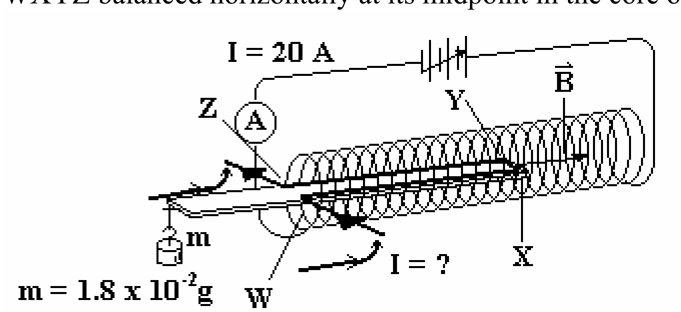
116. An electron enters a parallel plate apparatus 10 cm long and 2.0 cm wide, moving horizontally at 8.0×10^{7} m/s, as shown. If the potential difference across the plates is 600 V, determine the following.
(a) the vertical deflection of the electron from its original path
(b) the velocity with which it leaves the parallel plate apparatus, in both magnitude and direction



Hint : This problem may be treated the same as if you had a gravitational projectile whose motion is the resultant of uniform motion in the horizontal plane and uniform acceleration in the vertical plane.

117. A straight wire carries a current of 20 A vertically upward, in a vacuum. An electron moves at a speed of 5.0×10^{6} m/s, parallel to this wire but vertically downward, a distance of 10 cm from it. Calculate the magnitude and direction of the force on the electron. Will this force remain constant?

118. A coil 15 cm long with 100 turns lies in a horizontal plane, with a light frame supporting conducting wire WXYZ balanced horizontally at its midpoint in the core of the coil, as shown.



Sides WX and YZ of the conductor are 5.0 cm long, and are parallel to the axis of the coil, whereas side XY is 1.5 cm long and perpendicular to the axis of the coil. The current flowing through the coil is 20 A. What current must flow through the conductor WXYZ in order to keep it in horizontal balance, when a mass of 1.8 $\times 10^{-2}$ g hangs from the far end of the light frame that holds the conductor?

119. A wire, whose linear mass density is 150 g/m, carries a current of 40 A (supplied by a flexible connection of negligible weight). This wire lies parallel to, and on top of, another horizontal wire on a table. What current must flow through the bottom wire in order to repel and support the top wire at a height of 4.0 cm above it? (There are frictionless guide plates to keep it on line.)

120. Two football fans are listening to the Grey Cup game on radio, one in Montreal where it is being played, and the other in the Northwest Territories, 6000 km away. The distant signal is transmitted by microwaves, using a communications satellite at an altitude of 36 000 km. Making whatever assumptions seem reasonable, determine how much sooner the fan in Montreal hears the results of any play.

121. Ultrasonic waves are used to observe babies as they develop from conception to birth. Typical frequencies are 30 000 Hz to 45 000 Hz.
(a) What would be the typical wavelengths if these were radio waves?

(b) What are the actual wavelengths, in air, given that they are high-frequency sound waves with a velocity of 340 m/s?

122. Calculate the velocity of a proton, moving in a circular path of radius 8.0 cm, in a plane perpendicular to a 1.5 T magnetic field. What voltage would be required to accelerate the proton from rest, in a vacuum?

123. A conductor 40 cm long has a mass of 15 g and lies in a horizontal position, at a 90° angle to the field lines of a uniform horizontal magnetic field of 0.20 T. What must the current in the conductor be, so that the magnetic force on it will support its own weight?

124. An alpha particle ($q = +3.2 \times 10^{-19}$ C, $m = 6.7 \times 10^{-27}$ kg) is accelerated by a potential difference of 1200 V, and then enters a uniform magnetic field of magnitude 0.25 T, moving at 90° to the field. What is the magnetic force acting on it?

Electrostatics Extra Study Questions
Answer Section

SHORT ANSWER

1. ANS:

(a) Since $F \propto \dfrac{1}{d^2}$

$$\frac{F_1}{F_2} = \left(\frac{d_2}{d_1}\right)^2$$

Then, $F_2 = F_1\left(\dfrac{d_1}{d_2}\right)^2$

$$= \left(5.0 \times 10^{-5}\ \text{N}\right)\left(\frac{1}{2}\right)^2$$

$$= 1.3 \times 10^{-5}\ \text{N}$$

(b) Since $F \propto q_A q_B$

$$\frac{F_1}{F_2} = \frac{q_{A1} q_{B1}}{q_{A2} q_{B2}}$$

Then, $F_2 = F_1\left(\dfrac{q_{A2}}{q_{A1}}\right)\left(\dfrac{q_{B2}}{q_{B1}}\right)$

$$= \left(5.0 \times 10^{-5}\ \text{N}\right)\left(\frac{1}{2}\right)\left(\frac{3}{1}\right)$$

$$= 7.5 \times 10^{-5}\ \text{N}$$

(c) Since $F \propto \dfrac{q_A q_B}{d^2}$

$$\frac{F_1}{F_2} = \left(\frac{q_{A1}}{q_{A2}}\frac{q_{B1}}{q_{B2}}\right)\left(\frac{d_2}{d_1}\right)^2$$

$$\text{Then, } F_2 = F_1\left(\frac{q_{A2}}{q_{A1}}\right)\left(\frac{q_{B2}}{q_{B1}}\right)\left(\frac{d_1}{d_2}\right)^2$$

$$= \left(5.0 \times 10^{-5}\ \text{N}\right)\left(\frac{3}{1}\right)\left(\frac{1}{2}\right)\left(\frac{1}{2}\right)^2$$

$$= 1.9 \times 10^{-5}\ \text{N}$$

REF: K/U OBJ: 7.2 LOC: EG1.03 KEY: FOP 15.3, p.582
MSC: SP

2. ANS:

$$F = k\frac{q_1 q_2}{d^2}$$

$$= \left(9.0 \times 10^9\ \text{N}\cdot\text{m}^2/\text{C}^2\right)\frac{\left(1.0 \times 10^{-12}\ \text{C}\right)\left(1.0 \times 10^{-12}\ \text{C}\right)}{(1.0\ \text{m})^2}$$

$$= 9.0 \times 10^{-15}\ \text{N}$$

REF: K/U OBJ: 7.2 LOC: EG1.03 KEY: FOP 15.3, p.582
MSC: SP

3. ANS:

(a) $F \propto Q_1 Q_2$

$$\frac{F_2}{F_1} = \frac{\left(Q_1 Q_2\right)_2}{\left(Q_1 Q_2\right)_1}$$

$$F_2 = F_1\frac{\left(Q_1 Q_2\right)_2}{\left(Q_1 Q_2\right)_1}$$

$$= \left(3.0 \times 10^{-6}\ \text{N}\right)(2)(2)$$

$$= 1.2 \times 10^{-5}\ \text{N}$$

(b) $F_2 = F_1 \frac{(Q_1Q_2)_2}{(Q_1Q_2)_1}$ where $(Q_1)_2 = \frac{1}{2}(Q_1)_1$

$= (3.0 \times 10^{-6}\ \text{N})\left(\frac{1}{2}\right)(1)$

$= 1.5 \times 10^{-6}\ \text{N}$

(c) $F \propto \frac{1}{d^2}$

$\frac{F_2}{F_1} = \frac{d_1{}^2}{d_2{}^2}$

$F_2 = F_1 \frac{d_1{}^2}{d_2{}^2}$

$= (3.0 \times 10^{-6}\ \text{N}) \frac{(10\ \text{cm})^2}{(30\ \text{cm})^2}$

$= 3.3 \times 10^{-7}\ \text{N}$

REF: K/U OBJ: 7.2 LOC: EG1.03 KEY: FOP 15.3, p.583
MSC: P

4. ANS:

$F \propto \frac{1}{d^2}$

$\frac{F_2}{F_1} = \left(\frac{d_1}{d_2}\right)^2$

$F_2 = F_1 \left(\frac{d_1}{d_2}\right)^2$

(a) $F_2 = (3.6 \times 10^{-5}\ \text{N})\left(\frac{0.12\ \text{m}}{0.24\ \text{m}}\right)^2$

$= 9.0 \times 10^{-6}\ \text{N}$

(b) $F_2 = \left(3.6 \times 10^{-5}\ \text{N}\right)\left(\dfrac{0.12\ \text{m}}{0.30\ \text{m}}\right)^2$

$= 5.8 \times 10^{-6}\ \text{N}$

(c) $F_2 = \left(3.6 \times 10^{-5}\ \text{N}\right)\left(\dfrac{0.12\ \text{m}}{0.36\ \text{m}}\right)^2$

$= 4.0 \times 10^{-6}\ \text{N}$

REF: K/U OBJ: 7.2 LOC: EG1.03 KEY: FOP 15.3, p.583
MSC: P

5. ANS:

$$F = \frac{kQ_1Q_2}{d^2}$$

$$= \frac{\left(9.0 \times 10^9\ \text{N} \cdot \text{m}^2/\text{C}^2\right)\left(5.0 \times 10^{-8}\ \text{C}\right)\left(1.0 \times 10^{-7}\ \text{C}\right)}{\left(5.0 \times 10^{-2}\ \text{m}\right)^2}$$

$$= 1.8 \times 10^{-2}\ \text{N}$$

REF: K/U OBJ: 7.2 LOC: EG1.03 KEY: FOP 15.3, p.583
MSC: P

6. ANS:

$$F = \frac{kQ_1Q_2}{d^2}$$

$$= \frac{\left(9.0 \times 10^9\ \text{N} \cdot \text{m}^2/\text{C}^2\right)\left(1.5 \times 10^{-6}\ \text{C}\right)\left(3.2 \times 10^{-4}\ \text{C}\right)}{(1.5\ \text{m})^2}$$

$$= 1.9\ \text{N}$$

REF: K/U OBJ: 7.2 LOC: EG1.03 KEY: FOP 15.3, p.583
MSC: P

7. ANS:

Let the charges be q and $2q$ in magnitude.

$$F = \frac{kQ_1Q_2}{d^2}$$

$$\left(1.2 \times 10^{-9}\ \text{N}\right) = \frac{\left(9.0 \times 10^{9}\ \text{N}\cdot\text{m}^2/\text{C}^2\right)(q)(2q)}{\left(4.0 \times 10^{-2}\ \text{m}\right)^2}$$

$$q^2 = 1.07 \times 10^{-22}\ \text{C}^2$$

$$q = 1.0 \times 10^{-11}\ \text{C}$$

Then, $2q = 2.0 \times 10^{-11}\ \text{C}$

It doesn't matter which is positive.

REF: K/U OBJ: 7.2 LOC: EG1.03 KEY: FOP 15.3, p.583
MSC: P

8. ANS:

$$F = \frac{kQ_1Q_2}{d^2}$$

$$d = \sqrt{\frac{kQ_1Q_2}{F}}$$

$$= \sqrt{\frac{\left(9.0 \times 10^{9}\ \text{N}\cdot\text{m}^2/\text{C}^2\right)\left(1.1 \times 10^{-7}\ \text{C}\right)^2}{4.2 \times 10^{-4}\ \text{N}}}$$

$$= \sqrt{0.259\ \text{m}^2}$$

$$= 0.51\ \text{m}$$

REF: K/U OBJ: 7.2 LOC: EG1.03 KEY: FOP 15.3, p.583
MSC: P

9. ANS:

$$\vec{\varepsilon} = \frac{\vec{F}_e}{q}$$

$$= \frac{kq}{d^2}$$

$$= \frac{\left(9.0 \times 10^9 \text{ N} \cdot \text{m}^2/\text{C}^2\right)\left(1.6 \times 10^{-8} \text{ C}\right)}{(0.50 \text{ m})^2}$$

$$= 5.8 \times 10^2 \text{ N/C [radially outward]}$$

REF: K/U OBJ: 7.3 LOC: EG1.01 KEY: FOP 15.4, p.590
MSC: SP

10. ANS:

$$\vec{\varepsilon} = \frac{\vec{F}_e}{q}$$

$$= \frac{3.2 \text{ N [left]}}{-2.4 \times 10^{-6} \text{ C}}$$

$$= -1.3 \times 10^6 \text{ N/C [left], or } 1.3 \times 10^6 \text{ N/C [right]}$$

REF: K/U OBJ: 7.3 LOC: EG1.01 KEY: FOP 15.4, p.591
MSC: P

11. ANS:

$$F = q\varepsilon$$

$$= \left(2.5 \times 10^{-7} \text{ C}\right)(12 \text{ N/C})$$

$$= 3.0 \times 10^{-6} \text{ N}$$

REF: K/U OBJ: 7.3 LOC: EG1.01 KEY: FOP 15.4, p.592
MSC: P

12. ANS:

$$\vec{\varepsilon} = \frac{\vec{F}_e}{q}$$
$$= \frac{kQ}{d^2}$$
$$= \frac{\left(9.0 \times 10^9 \text{ N} \cdot \text{m}^2/\text{C}^2\right)\left(+5.4 \times 10^{-4} \text{ C}\right)}{(3.0 \text{ m})^2}$$
$$= 5.4 \times 10^5 \text{ N/C [right]}$$

REF: K/U OBJ: 7.3 LOC: EG1.01 KEY: FOP 15.4, p.592
MSC: P

13. ANS:

$\varepsilon_1 = \varepsilon_2 = 3.0 \times 10^3$ N/C
since ε is constant between the plates.

REF: K/U OBJ: 7.3 LOC: EG1.01 KEY: FOP 15.4, p.592
MSC: P

14. ANS:

$$V = \frac{kq}{r}$$
$$= \frac{\left(9.0 \times 10^9 \text{ N} \cdot \text{m}^2/\text{C}^2\right)\left(6.4 \times 10^{-6} \text{ C}\right)}{0.40 \text{ m}}$$
$$= 1.4 \times 10^5 \text{ J/C, or } 1.4 \times 10^5 \text{ V}$$

REF: K/U OBJ: 7.4 LOC: EG1.01 KEY: FOP 15.5, p.596
MSC: SP

15. ANS:

$$W = \Delta E_e$$
$$= q\Delta V$$
$$= \left(3.0 \times 10^{-7} \text{ C}\right)\left(1.20 \times 10^2 \text{ V}\right)$$
$$= 3.6 \times 10^{-5} \text{ J}$$

REF: K/U OBJ: 7.4 LOC: EG1.05 KEY: FOP 15.5, p.596
MSC: SP

16. ANS:

$$\varepsilon = \frac{V}{d}$$

$$= \frac{80\ \text{V}}{0.10\ \text{m}}$$

$$= 8.0 \times 10^{2}\ \text{N/C}$$

REF: K/U OBJ: 7.3 LOC: EG1.01 KEY: FOP 15.5, p.596
MSC: SP

17. ANS:
For parallel plates:

$$\varepsilon = \frac{V}{d}$$

$$d = \frac{V}{\varepsilon}$$

$$= \frac{90\ \text{V}}{400\ \text{N/C}}$$

$$= 0.23\ \text{m}$$

REF: K/U OBJ: 7.3 LOC: EG1.01 KEY: FOP 15.5, p.596
MSC: SP

18. ANS:

$$V = \frac{kQ}{r}$$

$$Q = \frac{rV}{k}$$

$$= \frac{(0.25\ \text{m})\left(-6.4 \times 10^{-4}\ \text{V}\right)}{\left(9.0 \times 10^{9}\ \text{N} \cdot \text{m}^{2}/\text{C}^{2}\right)}$$

$$= -1.8 \times 10^{-6}\ \text{C}$$

REF: K/U OBJ: 7.4 LOC: EG1.01 KEY: FOP 15.5, p.597
MSC: P

19. ANS:

$$V = \frac{W}{q}$$

$$= \frac{4.2 \times 10^{-3}\ \text{J}}{1.2 \times 10^{-6}\ \text{C}}$$

$$= 3.5 \times 10^{3}\ \text{V}$$

REF: K/U OBJ: 7.4 LOC: EG1.01 KEY: FOP 15.5, p.597
MSC: P

20. ANS:

$$\varepsilon = \frac{V}{d}$$

$$= \frac{300\ V}{\left(5.0 \times 10^{-3}\ \text{m}\right)}$$

$$= 6.0 \times 10^{4}\ \text{N/C}$$

REF: K/U OBJ: 7.3 LOC: EG1.01 KEY: FOP 15.5, p.597
MSC: P

21. ANS:

$$V = \varepsilon d$$

$$= \left(1.5 \times 10^{4}\ \text{N/C}\right)\left(1.2 \times 10^{-2}\ \text{m}\right)$$

$$= 1.8 \times 10^{2}\ V$$

REF: K/U OBJ: 7.3 LOC: EG1.01 KEY: FOP 15.5, p.597
MSC: P

22. ANS:

$$q = Ne$$

$$= \left(5.0 \times 10^{14}\right)\left(1.6 \times 10^{-19}\ \text{C}\right)$$

$$= 8.0 \times 10^{-5}\ \text{C}$$

The charge is negative as a result of the excess of electrons.

REF: K/U OBJ: 7.5 LOC: EG1.01 KEY: FOP 15.6, p.600
MSC: SP

23. ANS:

(a) The electric force must be up, to balance the downward force of gravity. Since the upper plate is positive, the latex sphere must be charged negatively, to be attracted to the upper plate and repelled by the lower plate. The electric field is downward, giving an upward force on a negative charge.

(b) For a parallel plate apparatus:

$$\varepsilon = \frac{V}{d}$$

$$= \frac{460 \text{ V}}{2.5 \times 10^{-2} \text{ N/C}}$$

$$= 1.84 \times 10^{4} \text{ N/C}$$

This field is directed downward.

(c) When the sphere is balanced,

$$F_e = F_g$$

$$q\varepsilon = mg$$

$$q = \frac{mg}{\varepsilon}$$

$$= \frac{\left(1.5 \times 10^{-15} \text{ kg}\right)\left(9.8 \text{ m/s}^2\right)}{1.84 \times 10^{4} \text{ N/C}}$$

$$= 8.0 \times 10^{-19} \text{ C}$$

(d) $N = \frac{q}{e}$

$$= \frac{8.0 \times 10^{-19} \text{ C}}{1.6 \times 10^{-19} \text{ C}}$$

$$= 5$$

There is an excess, since the charge was negative.

REF: K/U, C OBJ: 7.5 LOC: EG1.06 KEY: FOP 15.6, p.600
MSC: SP

24. ANS:

$$N = \frac{Q}{e}$$

$$= \frac{8.0 \times 10^{-8} \text{ C}}{1.6 \times 10^{-19} \text{ C}}$$

$$= 5.0 \times 10^{11} \text{ electrons}$$

REF: K/U OBJ: 7.5 LOC: EG1.01 KEY: FOP 15.6, p.601
MSC: P

25. ANS:

$$F = \frac{kQ_1Q_2}{d^2}$$

$$= \frac{\left(9.0 \times 10^9 \text{ N}\cdot\text{m}^2/\text{C}^2\right)(10^8)^2\left(-1.6 \times 10^{-19} \text{ C}\right)^2}{(1.0 \text{ m})^2}$$

$$= -2.3 \times 10^{-12} \text{ N}$$

REF: K/U OBJ: 7.2 LOC: EG1.03 KEY: FOP 15.6, p.601
MSC: P

26. ANS:

$$W = Vq$$

$$q = \frac{W}{V}$$

$$= \frac{0.24 \text{ J}}{1.5 \times 10^2 \text{ V}}$$

$$= 1.6 \times 10^{-3} \text{ C}$$

REF: K/U OBJ: 7.4 LOC: EG1.05 KEY: FOP 15.7, p.605
MSC: P

27. ANS:

$$W = Vq$$

$$= \frac{1}{2}mv^2$$

(a) $v = \sqrt{\frac{2Vq}{m}}$

$$= \sqrt{\frac{2\left(2.0 \times 10^3 \text{ V}\right)\left(3.2 \times 10^{-19} \text{ C}\right)}{6.6 \times 10^{-27} \text{ kg}}}$$

$$= \sqrt{19.4 \times 10^{10} (\text{m/s})^2}$$

$$= 4.4 \times 10^5 \text{ m/s}$$

(b) $v = \sqrt{\dfrac{2Vq}{m}}$ where $V = \dfrac{1}{2}\left(2.0 \times 10^{3}\ \text{V}\right)$

$$= \sqrt{\frac{2\left(1.0 \times 10^{3}\ \text{V}\right)\left(3.2 \times 10^{-19}\ \text{C}\right)}{6.6 \times 10^{-27}\ \text{kg}}}$$

$$= 3.1 \times 10^{5}\ \text{m/s}$$

REF: K/U OBJ: 7.6 LOC: EG1.01 KEY: FOP 15.7, p.605
MSC: P

28. ANS:

(a) $W = qV$

$$= \left(4.0 \times 10^{-7}\ \text{C}\right)\left(8.0 \times 10^{2}\ \text{V}\right)$$

$$= 3.2 \times 10^{-4}\ \text{J}$$

(b) $F = \dfrac{W}{d}$

$$= \frac{3.2 \times 10^{-4}\ \text{J}}{0.50\ \text{m}}$$

$$= 6.4 \times 10^{-4}\ \text{N}$$

(c) $E_k = W$

$$= 3.2 \times 10^{-4}\ \text{J}$$

(d) $\dfrac{1}{2}mv^{2} = E_k$

$$v = \sqrt{\frac{2E_k}{m}}$$

$$= \sqrt{\frac{(2)\left(3.2 \times 10^{-4}\ \text{J}\right)}{1.0 \times 10^{-5}\ \text{kg}}}$$

$$= 8.0\ \text{m/s}$$

REF: K/U OBJ: 7.6 LOC: EG1.01 KEY: FOP 15.7, p.605
MSC: P

29. ANS:

$$W = Vq = \frac{1}{2}mv^2$$

$$V = \frac{mv^2}{2q}$$

$$= \frac{\left(3.3 \times 10^{-27}\ \text{kg}\right)\left(5.0 \times 10^{6}\ \text{m/s}\right)^2}{(2)\left(1.6 \times 10^{-19}\ \text{C}\right)}$$

$$= 2.6 \times 10^{5}\ \text{V}$$

REF: K/U OBJ: 7.6 LOC: EG1.01 KEY: FOP 15.7, p.605
MSC: P

30. ANS:

$$F \propto \frac{Q_A Q_B}{d^2}$$

$$\frac{F_2}{F_1} = \frac{\left(Q_A Q_B\right)_2 {d_1}^2}{\left(Q_A Q_B\right)_1 {d_2}^2}$$

$$F_2 = F_1 \frac{\left(Q_A Q_B\right)_2}{\left(Q_A Q_B\right)_1}\left(\frac{d_1}{d_2}\right)^2$$

$$= \left(1.6 \times 10^{-2}\ \text{N}\right)\left(\frac{1}{2}\right)\left(\frac{1}{2}\right)\left(\frac{1}{2}\right)^2$$

$$= 1.0 \times 10^{-3}\ \text{N}$$

REF: K/U OBJ: 7.2 LOC: EG1.03 KEY: FOP 15.9, p.612
MSC: P

31. ANS:

$$F = \frac{kQ_1Q_2}{d^2}$$

$$d = \sqrt{\frac{kQ_1Q_2}{F}}$$

$$= \sqrt{\frac{\left(9.0 \times 10^9 \text{ N} \cdot \text{m}^2/\text{C}^2\right)\left(1.6 \times 10^{-19} \text{ C}\right)^2}{4.0 \times 10^{-11} \text{ N}}}$$

$$= \sqrt{5.76 \times 10^{-18} \text{ m}^2}$$

$$= 2.4 \times 10^{-9} \text{ m}$$

REF: K/U OBJ: 7.2 LOC: EG1.03 KEY: FOP 15.9, p.612
MSC: P

32. ANS:

$$mg = \frac{kq_1q_2}{d^2}$$

$$d = \sqrt{\frac{kq_1q_2}{mg}}$$

$$= \sqrt{\frac{\left(9.0 \times 10^9 \text{ N} \cdot \text{m}^2/\text{C}^2\right)\left(1.6 \times 10^{-19} \text{ C}\right)^2}{\left(9.1 \times 10^{-21} \text{ kg}\right)\left(9.8 \text{ N/kg}\right)}}$$

$$= \sqrt{25.8 \text{ m}^2}$$

$$= 5.1 \text{ m}$$

REF: K/U OBJ: 7.2 LOC: EG1.03 KEY: FOP 15.9, p.613
MSC: P

33. ANS:

$$\vec{\varepsilon} = \frac{\vec{F}_e}{q}$$

$$= \frac{6.0 \times 10^{-6} \text{ N [right]}}{+1.0 \times 10^{-6} \text{ C}}$$

$$= 6.0 \text{ N/C [right]}$$

(b) $\vec{F}_e = q\vec{\varepsilon}$

$$= \left(-7.2 \times 10^{-4}\text{ C}\right)\left(6.0\text{ N/C [right]}\right)$$

$$= -4.3 \times 10^{-3}\text{ N [right], or } 4.3 \times 10^{-3}\text{ N [left]}$$

REF: K/U OBJ: 7.3 LOC: EG1.01 KEY: FOP 15.9, p.613
MSC: P

34. ANS:

$$\vec{\varepsilon} = \frac{\vec{F}_e}{q}$$

$$= \frac{kQq\text{ [right]}}{r^2 q}$$

$$= \frac{\left(9.0 \times 10^9\text{ N}\cdot\text{m}^2/\text{C}^2\right)\left(8.0 \times 10^{-3}\text{ C}\right)\text{ [right]}}{(1.5\text{ m})^2}$$

$$= 3.2 \times 10^7\text{ N/C [right]}$$

REF: K/U OBJ: 7.3 LOC: EG1.01 KEY: FOP 15.9, p.613
MSC: P

35. ANS:

$$\vec{\varepsilon} = \vec{\varepsilon}_x + \vec{\varepsilon}_y$$

$$\varepsilon = \frac{-kQ_x}{d_x^2} + \frac{kQ_y}{d_y^2} \quad \text{(where right is positive)}$$

$$= \frac{-\left(9.0 \times 10^9\text{ N}\cdot\text{m}^2/\text{C}^2\right)\left(2.0 \times 10^{-5}\text{ C}\right)}{(0.90\text{ m})^2} + \frac{\left(9.0 \times 10^9\text{ N}\cdot\text{m}^2/\text{C}^2\right)\left(8.0 \times 10^{-6}\text{ C}\right)}{(0.30\text{ m})^2}$$

$$= -2.22 \times 10^5\text{ N/C} + 8.00 \times 10^5\text{ N/C}$$

$$\vec{\varepsilon} = 5.8 \times 10^5\text{ N/C [right]}$$

REF: K/U OBJ: 7.3 LOC: EG1.06 KEY: FOP 15.9, p.613
MSC: P

36. ANS:

$$\varepsilon_1 = 4.8 \times 10^2\text{ N/C}$$

(a) ε is independent of d.

$$\therefore \; \varepsilon_2 = \varepsilon_1 = 4.8 \times 10^2\text{ N/C}$$

(b) $\varepsilon \propto Q$

$$\therefore \ \varepsilon_3 = \varepsilon_1 \left(\frac{Q_3}{Q_1}\right)$$

$$= \left(4.8 \times 10^2 \text{ N/C}\right)(3)$$

$$= 1.4 \times 10^2 \text{ N/C}$$

(c) When plates are connected, $Q_4 = 0$..
$\therefore \ \varepsilon_4 = 0$

REF: K/U OBJ: 7.3 LOC: EG1.01 KEY: FOP 15.9, p.613
MSC: P

37. ANS:

$$V = \frac{kQ}{r}$$

$$= \frac{\left(9.0 \times 10^9 \text{ N} \cdot \text{m}^2/\text{C}^2\right)\left(4.5 \times 10^{-4} \text{ C}\right)}{(0.50 \text{ m})}$$

$$= 8.1 \times 10^6 \text{ V}$$

REF: K/U OBJ: 7.4 LOC: EG1.01 KEY: FOP 15.9, p.614
MSC: P

38. ANS:

$$\Delta E_k = q\Delta V$$

$$= \left(1.6 \times 10^{-19} \text{ C}\right)\left(2.5 \times 10^4 \text{ V}\right)$$

$$= 4.0 \times 10^{-15} \text{ J}$$

REF: K/U OBJ: 7.6 LOC: EG1.01 KEY: FOP 15.9, p.614
MSC: P

39. ANS:

$$E_e = \frac{kQ_1Q_2}{r}$$

$$= \frac{\left(9.0 \times 10^9 \text{ N} \cdot \text{m}^2/\text{C}^2\right)\left(1.6 \times 10^{-19} \text{ C}\right)^2}{\left(1.0 \times 10^{-15} \text{ m}\right)}$$

$$= 2.3 \times 10^{-13} \text{ J}$$

Note: This takes an accelerating potential difference of 1.4×10^6 V.

REF: K/U OBJ: 7.4 LOC: EG1.05 KEY: FOP 15.9, p.614
MSC: P

40. ANS:

$$\varepsilon = \frac{V}{d}$$

$$= \frac{450 \text{ V}}{2.0 \times 10^{-2} \text{ m}}$$

$$= 2.3 \times 10^4 \text{ N/C}$$

REF: K/U OBJ: 7.3 LOC: EG1.01 KEY: FOP 15.9, p.614
MSC: P

41. ANS:

$$V = \varepsilon d$$

$$= \left(2.5 \times 10^3 \text{ N/C}\right)\left(8.0 \times 10^{-2} \text{ m}\right)$$

$$= 2.0 \times 10^2 \text{ V}$$

REF: K/U OBJ: 7.3 LOC: EG1.01 KEY: FOP 15.9, p.614
MSC: P

42. ANS:

$$d = \frac{V}{\varepsilon}$$

$$= \frac{600 \text{ V}}{1.2 \times 10^4 \text{ N/C}}$$

$$= 5.0 \times 10^{-2} \text{ m, or } 5.0 \text{ cm}$$

REF: K/U OBJ: 7.3 LOC: EG1.01 KEY: FOP 15.9, p.614
MSC: P

43. ANS:

$$N = \frac{Q}{e}$$
$$= \frac{8.0 \times 10^{-12}\ \text{C}}{1.6 \times 10^{-19}\ \text{C}}$$
$$= 5.0 \times 10^{7}$$

REF: K/U OBJ: 7.5 LOC: EG1.01 KEY: FOP 15.9, p.614
MSC: P

44. ANS:

$$W = qV$$
$$= \Delta E_k$$
$$= \frac{1}{2}mv^2$$

$$v = \sqrt{\frac{2qV}{m}}$$
$$= \sqrt{\frac{(2)\left(1.6 \times 10^{-19}\ \text{C}\right)\left(5.0 \times 10^{2}\ \text{V}\right)}{\left(9.1 \times 10^{-31}\ \text{kg}\right)}}$$
$$= \sqrt{1.76 \times 10^{14}\ (\text{m/s})^2}$$
$$= 1.3 \times 10^{7}\ \text{m/s}$$

REF: K/U OBJ: 7.6 LOC: EG1.01 KEY: FOP 15.9, p.615
MSC: P

45. ANS:

$$\Delta E_k = qV$$
$$V = \frac{\Delta E_k}{q}$$
$$= \frac{1.9 \times 10^{-15}\ \text{J}}{3.2 \times 10^{-19}\ \text{C}}$$
$$= 5.9 \times 10^{3}\ \text{V}$$

REF: K/U OBJ: 7.6 LOC: EG1.01 KEY: FOP 15.9, p.615
MSC: P

46. ANS:

In the general case, the magnitude of the force is given by

$$F = BIl \sin\theta$$
$$= (0.60\ \text{T})(15\ \text{A})(0.10\ \text{m}) \sin\theta$$
$$= 0.90 \sin\theta\ \text{N}$$

(a) when $\theta = 90°$, sin $\theta = 1$, and $F = 0.90$ N

(b) when $\theta = 45°$, sin $\theta = 0.707$, and $F = 0.90$ N(0.707) = 0.64 N

(c) when $\theta = 0°$, sin $\theta = 0$, and $F = 0$ N

In each case above, the direction of the force is that given by the right-hand rule.

REF: K/U OBJ: 8.3 LOC: EG1.08 KEY: FOP 16.3, p.628
MSC: SP

47. ANS:

$$F = BIl \sin\theta$$
$$= (0.20\ \text{T})(15\ \text{A})(0.25\ \text{m})(\sin 90°)$$
$$= 0.75\ \text{N}$$

REF: K/U OBJ: 8.3 LOC: EG1.08 KEY: FOP 16.3, p.629
MSC: P

48. ANS:

$$l = \frac{F}{BI\sin\theta}$$
$$= \frac{0.10\ \text{N}}{(0.033\ \text{T})(20\ \text{A})(\sin 90°)}$$
$$= 0.15\ \text{m}$$

REF: K/U OBJ: 8.3 LOC: EG1.08 KEY: FOP 16.3, p.629
MSC: P

49. ANS:

$$B = \frac{F}{Il\sin\theta}$$
$$= \frac{6.0 \times 10^{-5}\ \text{N}}{(15\ \text{A})(1.0\ \text{m})(\sin 90°)}$$
$$= 4.0 \times 10^{-5}\ \text{T}$$

REF: K/U OBJ: 8.3 LOC: EG1.08 KEY: FOP 16.3, p.629
MSC: P

50. ANS:

$$F = BIl\sin\theta$$
$$= \left(5.0 \times 10^{-5}\ \text{T}\right)(200\ \text{A})(50\ \text{m})(\sin 45°)$$
$$= 0.35\ \text{N}$$

REF: K/U OBJ: 8.3 LOC: EG1.08 KEY: FOP 16.3, p.629
MSC: P

51. ANS:

$$F = qvB\sin\theta$$
$$= \left(1.6 \times 10^{-19}\ \text{C}\right)\left(8.6 \times 10^{4}\ \text{m/s}\right)(1.2\ \text{T})(\sin 90°)$$
$$= 1.7 \times 10^{-14}\ \text{N [E]}$$

The direction is given by the right-hand rule.

REF: K/U OBJ: 8.2 LOC: EG1.08 KEY: FOP 16.3, p.632
MSC: P

52. ANS:

$$B = \frac{F}{qv\sin\theta}$$
$$= \frac{5.1 \times 10^{-14}\ \text{N}}{\left(1.6 \times 10^{-19}\ \text{C}\right)\left(2.0 \times 10^{6}\ \text{m/s}\right)(\sin 90°)}$$
$$\vec{B} = 0.16\ \text{T [horizontal, toward observer]}$$

The direction is given by the right-hand rule.

REF: K/U OBJ: 8.2 LOC: EG1.08 KEY: FOP 16.3, p.632
MSC: P

53. ANS:

$$r = \frac{mv}{Bq}$$
$$= \frac{\left(6.7 \times 10^{-27}\ \text{kg}\right)\left(1.5 \times 10^{7}\ \text{m/s}\right)}{(2.4\ \text{T})\left(3.2 \times 10^{-19}\ \text{C}\right)}$$
$$= 0.13\ \text{m}$$

REF: K/U OBJ: 8.2 LOC: EG1.08 KEY: FOP 16.3, p.633
MSC: P

54. ANS:

$$F = qvB\sin\theta$$
$$= (100\ \text{C})(200\ \text{m/s})\left(5.0\times10^{-5}\ \text{T}\right)(\sin 90°)$$
$$= 1.0\ \text{N}$$

REF: K/U OBJ: 8.2 LOC: EG1.08 KEY: FOP 16.3, p.633
MSC: P

55. ANS:

$$B = \mu_0\left(\frac{I}{2\pi r}\right)$$
$$= \frac{\left(4\pi\times10^{-7}\ \text{T}\cdot\text{m/A}\right)(100\ \text{A})}{2\pi(0.15\ \text{m})}$$
$$= 1.3\times10^{-4}\ \text{T}$$

REF: K/U OBJ: 8.4 LOC: EG1.01 KEY: FOP 16.4, p.635
MSC: SP

56. ANS:

$$B = \mu_0\left(\frac{I}{2\pi r}\right)$$
$$= \frac{\left(4\pi\times10^{-7}\ \text{T}\cdot\text{m/A}\right)(60\ \text{A})}{2\pi(0.20\ \text{m})}$$
$$= 6.0\times10^{-5}\ \text{T}$$

REF: K/U OBJ: 8.4 LOC: EG1.01 KEY: FOP 16.4, p.635
MSC: P

57. ANS:

$$I = \frac{2\pi rB}{\mu_0}$$
$$= \frac{(2\pi)(0.10\ \text{m})\left(2.4\times10^{-5}\ \text{T}\right)}{\left(4\pi\times10^{-7}\text{T}\cdot\text{m/A}\right)}$$
$$= 12\ \text{A}$$

REF: K/U OBJ: 8.4 LOC: EG1.01 KEY: FOP 16.4, p.635
MSC: P

58. ANS:

$$r = \frac{\mu_0 I}{2\pi r B}$$

$$= \frac{\left(4\pi \times 10^{-7}\ \mathrm{T \cdot m/A}\right)(200\ \mathrm{A})}{(2\pi)\left(8.0 \times 10^{-4}\ \mathrm{T}\right)}$$

$$= 5.0 \times 10^{-2}\ \mathrm{m}$$

REF: K/U OBJ: 8.4 LOC: EG1.01 KEY: FOP 16.4, p.635
MSC: P

59. ANS:

$$B_1 = \mu_0\left(\frac{I}{2\pi r}\right)$$

$$= \frac{(4\pi \times 10^{-7}\ \mathrm{T \cdot m/A})(10\ \mathrm{A})}{(2\pi)(0.50\ \mathrm{m})}$$

$$= 4.0 \times 10^{-6}\ \mathrm{T}$$

And $B_2 = 8.0 \times 10^{-6}\ \mathrm{T}$

Then,
(a) If I_1 and I_2 are in opposite directions, B_1 and B_2 are in the same direction, so that

$$B = B_2 + B_1$$

$$= 1.2 \times 10^{-5}\ \mathrm{T}$$

(b) If I_1 and I_2 are in the same direction, B_1 and B_2 are in opposite directions, so that

$$B = B_2 - B_1$$

$$= 4.0 \times 10^{-6}\ \mathrm{T}$$

REF: K/U OBJ: 8.4 LOC: EG1.01 KEY: FOP 16.3, p.635
MSC: P

60. ANS:

$$B = \mu_0\left(\frac{I}{2\pi r}\right)$$

(a) $B = \mu_0\left(\frac{0}{2\pi r}\right) = 0\ \mathrm{T}$

(b) $I = \dfrac{\pi(2.5\ \text{cm})^2}{\pi(5.0\ \text{cm})^2}(1000\ \text{A})$

$= 250\ \text{A}$

$$B = \frac{\left(4\pi \times 10^{-7}\ \text{T}\cdot\text{m/A}\right)(250\ \text{A})}{(2\pi)\left(2.5 \times 10^{-2}\ \text{m}\right)}$$

$$= 2.0 \times 10^{-3}\ \text{T}$$

(c) $B = \dfrac{\left(4\pi \times 10^{-7}\ \text{T}\cdot\text{m/A}\right)(1000\ \text{A})}{(2\pi)\left(5.0 \times 10^{-2}\ \text{m}\right)}$

$= 4.0 \times 10^{-3}\ \text{T}$

(d) $B = \dfrac{\left(4\pi \times 10^{-7}\ \text{T}\cdot\text{m/A}\right)(1000\ \text{A})}{(2\pi)\left(7.5 \times 10^{-2}\ \text{m}\right)}$

$= 2.7 \times 10^{-3}\ \text{T}$

REF: K/U OBJ: 8.4 LOC: EG1.01 KEY: FOP 16.4, p.636
MSC: P

61. ANS:

$$B = \mu_0\left(\frac{NI}{L}\right)$$

$$= \frac{\left(4\pi \times 10^{-7}\ \text{T}\cdot\text{m/A}\right)(300)(10\ \text{A})}{5.0 \times 10^{-2}\ \text{m}}$$

$$= 7.5 \times 10^{-2}\ \text{T}$$

REF: K/U OBJ: 8.4 LOC: EG1.01 KEY: FOP 16.4, p.637
MSC: SP

62. ANS:

$$B = \mu_0\left(\frac{NI}{L}\right)$$

$$N = \frac{BL}{\mu_0 I}$$

$$= \frac{\left(5.0 \times 10^{-2}\ \text{T}\right)(0.15\ \text{m})}{\left(4.7 \times 10^{-7}\ \text{T}\cdot\text{m/A}\right)(12\ \text{A})}$$

$$= 5.0 \times 10^{2}\ \text{turns}$$

REF: K/U OBJ: 8.4 LOC: EG1.01 KEY: FOP 16.4, p.637
MSC: P

63. ANS:

$$B = \mu_0\left(\frac{NI}{L}\right)$$

$$= \frac{\left(4\pi \times 10^{-7}\ \text{T}\cdot\text{m/A}\right)(420)(6.0\ \text{A})}{(0.10\ \text{m})}$$

$$= 3.2 \times 10^{-2}\ \text{T}$$

REF: K/U OBJ: 8.4 LOC: EG1.01 KEY: FOP 16.4, p.637
MSC: P

64. ANS:

$$I = \frac{BL}{\mu_0 N}$$

$$= \frac{\left(1.4 \times 10^{-2}\ \text{T}\right)\left(8.0 \times 10^{-2}\ \text{m}\right)}{\left(4\pi \times 10^{-7}\ \text{T}\cdot\text{m/A}\right)(400)}$$

$$= 2.2\ \text{A}$$

REF: K/U OBJ: 8.4 LOC: EG1.01 KEY: FOP 16.4, p.637
MSC: P

65. ANS:

$$\frac{F}{l} = \frac{\mu_0 I_1 I_2}{2\pi d}$$

$$F = \frac{\mu_0 I_1 I_2 l}{2\pi d}$$

$$= \frac{\left(4\pi \times 10^{-7}\ \mathrm{T \cdot m/A}\right)(4.0\ \mathrm{A})(10.0\ \mathrm{A})(2.0\ \mathrm{m})}{2\pi(0.25\ \mathrm{m})}$$

$$= 6.4 \times 10^{-5}\ \mathrm{N}$$

REF: K/U OBJ: 8.3 LOC: EG1.08 KEY: FOP 16.4, p.639
MSC: SP

66. ANS:

$$\frac{F}{l} = \frac{\mu_0 I_1 I_2}{2\pi d}$$

$$= \frac{\left(4\pi \times 10^{-7}\ \mathrm{T \cdot m/A}\right)(8.0\ \mathrm{A})(8.0\ \mathrm{A})}{(2\pi)\left(1.0 \times 10^{-2}\ \mathrm{m}\right)}$$

$$= 1.3 \times 10^{-3}\ \mathrm{N/m}$$

REF: K/U OBJ: 8.3 LOC: EG1.08 KEY: FOP 16.4, p.639
MSC: P

67. ANS:

$$I^2 = \frac{2\pi d F}{\mu_0 l}$$

$$I = \sqrt{\frac{(2\pi)(0.12\ \mathrm{m})\left(2.0 \times 10^{-2}\ \mathrm{N}\right)}{\left(4\pi \times 10^{-7}\ \mathrm{T \cdot m/A}\right)(5.0\ \mathrm{m})}}$$

$$= \sqrt{24 \times 10^{2}\ \mathrm{A}^2}$$

$$= 49\ \mathrm{A}$$

REF: K/U OBJ: 8.3 LOC: EG1.08 KEY: FOP 16.4, p.639
MSC: P

68. ANS:

$$d = \frac{\mu_0 I_1 I_2}{2\pi\left(\frac{F}{l}\right)}$$

$$= \frac{\left(4\pi \times 10^{-7}\ \text{T}\cdot\text{m/A}\right)(5.0\ \text{A})(10\ \text{A})}{(2\pi)\left(3.6 \times 10^{-4}\ \text{N/m}\right)}$$

$$= 2.8 \times 10^{-2}\ \text{m}$$

REF: K/U OBJ: 8.3 LOC: EG1.08 KEY: FOP 16.4, p.639
MSC: P

69. ANS:

$$\frac{F}{l} = \frac{\mu_0 I_1 I_2}{2\pi d}$$

$$= \frac{\left(4\pi \times 10^{-7}\ \text{T}\cdot\text{m/A}\right)(1.0\ \text{A})(1.0\ \text{A})}{(2\pi)\left(2.0 \times 10^{-3}\ \text{m}\right)}$$

$$= 1.0 \times 10^{-4}\ \text{N/m}$$

REF: K/U OBJ: 8.3 LOC: EG1.08 KEY: FOP 16.3, p.639
MSC: P

70. ANS:

$$F = BlI\sin\theta$$

$$B = \frac{F}{lI\sin\theta}$$

$$= \frac{(0.40\ \text{N})}{\left(1.5 \times 10^{-1}\ \text{m}\right)\left(2.0 \times 10^{1}\ \text{A}\right)(1)}$$

$$= 1.3 \times 10^{-1}\ \text{N/A, or } 0.13\ \text{T}$$

REF: K/U OBJ: 8.3 LOC: EG1.08 KEY: FOP 16.11, p.668
MSC: P

71. ANS:

$$F = BlI\sin\theta$$

$$= (0.50\ \text{T})(0.25\ \text{m})(4.0\ \text{A})(\sin 45^\circ)$$

$$= 3.5 \times 10^{-1}\ \text{N, or } 0.35\ \text{N}$$

REF: K/U OBJ: 8.3 LOC: EG1.08 KEY: FOP 16.11, p.668
MSC: P

72. ANS:

$$F = qvB\sin\theta$$
$$= \left(1.6 \times 10^{-19}\ \text{C}\right)\left(3.2 \times 10^{6}\ \text{m/s}\right)(1.2\ \text{T})(\sin 90°)$$
$$\vec{F} = 6.1 \times 10^{-13}\ \text{N}\ [\text{vertically down}]$$

According to the right-hand rule.

REF: K/U OBJ: 8.2 LOC: EG1.08 KEY: FOP 16.11, p.669
MSC: P

73. ANS:

$$F = qvB\sin\theta$$
$$v = \frac{F}{qB\sin\theta}$$
$$= \frac{\left(2.6 \times 10^{-16}\ \text{N}\right)}{\left(1.6 \times 10^{-19}\ \text{C}\right)\left(2.0 \times 10^{-3}\ \text{T}\right)(\sin 90°)}$$
$$= 8.1 \times 10^{5}\ \text{m/s}$$

REF: K/U OBJ: 8.2 LOC: EG1.08 KEY: FOP 16.11, p.669
MSC: P

74. ANS:

$$B = \mu_0\left(\frac{I}{2\pi r}\right)$$
$$= \left(4\pi \times 10^{-7}\ \text{T}\cdot\text{m/A}\right)\left(\frac{(12\ \text{A})}{2\pi\left(2.0 \times 10^{-1}\ \text{m}\right)}\right)$$
$$\vec{B} = 1.2 \times 10^{-5}\ \text{T}\ [\text{horizontally, south}]$$

According to the right-hand rule.

REF: K/U OBJ: 8.4 LOC: EG1.01 KEY: FOP 16.11, p.669
MSC: P

75. ANS:

$$B = \mu_0\left(\frac{I}{2\pi r}\right)$$

$$I = \frac{2\pi r B}{\mu_0}$$

$$= \frac{(2\pi)\left(1.0 \times 10^{-1}\ \text{m}\right)\left(1.0 \times 10^{-4}\ \text{T}\right)}{\left(4\pi \times 10^{-7}\ \text{T}\cdot\text{m/A}\right)}$$

$$= 50\ \text{A}$$

REF: K/U OBJ: 8.4 LOC: EG1.01 KEY: FOP 16.11, p.669
MSC: P

76. ANS:

$$B = \mu_0\left(\frac{NI}{L}\right)$$

$$= \frac{\left(4\pi \times 10^{-7}\ \text{T}\cdot\text{m/A}\right)\left(1.2 \times 10^{3}\right)(1.0\ \text{A})}{\left(1.0 \times 10^{-1}\ \text{m}\right)}$$

$$= 1.5 \times 10^{-2}\ \text{T}$$

REF: K/U OBJ: 8.4 LOC: EG1.01 KEY: FOP 16.11, p.669
MSC: P

77. ANS:

$$F = \frac{\mu_0 I_1 I_2 l}{2\pi d}$$

$$= \frac{\left(4\pi \times 10^{-7}\ \text{T}\cdot\text{m/A}\right)(100\ \text{A})(100\ \text{A})(50\ \text{m})}{(2\pi)\left(1.0 \times 10^{-1}\ \text{m}\right)}$$

$$= 1.0\ \text{N}$$

REF: K/U OBJ: 8.3 LOC: EG1.08 KEY: FOP 16.11, p.670
MSC: P

78. ANS:

$$\frac{q}{m} = \frac{v}{Br}$$

$$= \frac{\left(6.0 \times 10^{6} \text{ m/s}\right)}{\left(3.2 \times 10^{-2} \text{ T}\right)\left(1.8 \times 10^{-2} \text{ m}\right)}$$

$$= 1.0 \times 10^{10} \text{ C/kg}$$

REF: K/U OBJ: 8.2 LOC: EG1.01 KEY: FOP 16.11, p.670
MSC: P

79. ANS:

$$v = \frac{qrB}{m}$$

$$= \frac{\left(1.6 \times 10^{-19} \text{ C}\right)(1.8 \text{ T})\left(3.0 \times 10^{-2} \text{ m}\right)}{\left(1.67 \times 10^{-27} \text{ kg}\right)}$$

$$= 5.2 \times 10^{6} \text{ m/s}$$

REF: K/U OBJ: 8.2 LOC: EG1.01 KEY: FOP 16.11, p.670
MSC: P

80. ANS:

$$m = \frac{qBr}{v}$$

$$= \frac{\left(1.6 \times 10^{-19} \text{ C}\right)\left(1.0 \times 10^{-3} \text{ T}\right)(0.40 \text{ m})}{\left(1.9 \times 10^{4} \text{ m/s}\right)}$$

$$= 3.4 \times 10^{-27} \text{ kg}$$

REF: K/U OBJ: 8.2 LOC: EG1.01 KEY: FOP 16.11, p.670
MSC: P

81. ANS:

(a) $\frac{1}{2}mv^2 = qV$

$$v = \sqrt{\frac{2qV}{m}}$$

$$= \sqrt{\frac{(2)\left(1.6 \times 10^{-19}\ \text{C}\right)\left(1.0 \times 10^{5}\ \text{V}\right)}{\left(3.9 \times 10^{-25}\ \text{kg}\right)}}$$

$$= \sqrt{8.21 \times 10^{10}\ (\text{m/s})^2}$$

$$= 2.9 \times 10^{5}\ \text{m/s}$$

(b) $r = \frac{mv}{qB}$

$$= \frac{\left(3.9 \times 10^{-25}\ \text{kg}\right)\left(2.9 \times 10^{5}\ \text{m/s}\right)}{\left(1.6 \times 10^{-19}\ \text{C}\right)(0.10\ \text{T})}$$

$$= 7.1 \times 10^{0}\ \text{m, or } 7.1\ \text{m}$$

REF: K/U OBJ: 8.2 LOC: EGV.01 KEY: FOP 16.11, p.670
MSC: P

82. ANS:

(a) $f = \frac{c}{\lambda}$

$$= \frac{3.0 \times 10^{8}\ \text{m/s}}{1.8 \times 10^{-2}\ \text{m}}$$

$$= 1.7 \times 10^{10}\ \text{Hz}$$

(b) $\lambda = \frac{c}{f}$

$$= \frac{3.0 \times 10^{8}\ \text{m/s}}{3.2 \times 10^{10}\ \text{Hz}}$$

$$= 9.4 \times 10^{-3}\ \text{m}$$

(c) $\lambda = \frac{c}{f}$

$= \frac{3.0 \times 10^{8} \text{ m/s}}{60 \text{ Hz}}$

$= 5.0 \times 10^{6} \text{ m}$

(d) $f = \frac{c}{\lambda}$

$= \frac{3.0 \times 10^{8} \text{ m/s}}{6.50 \times 10^{-7} \text{ m}}$

$= 4.6 \times 10^{14} \text{ Hz}$

REF: K/U OBJ: 9.6 LOC: WA1.01 KEY: FOP 16.11, p.670
MSC: P

83. ANS:

(a) $r = \frac{mv}{Bq}$

$= \frac{\left(9.1 \times 10^{-31} \text{ kg}\right)\left(4.0 \times 10^{6} \text{ m/s}\right)}{\left(5.0 \times 10^{-3} \text{ T}\right)\left(1.6 \times 10^{-19} \text{ C}\right)}$

$= 4.6 \times 10^{-3} \text{ m, or } 4.6 \text{ mm}$

(b) $qV = \frac{1}{2}mv^{2}$

$V = \frac{mv^{2}}{2q}$

$= \frac{\left(9.1 \times 10^{-31} \text{ kg}\right)\left(4.0 \times 10^{6} \text{ m/s}\right)^{2}}{2\left(1.6 \times 10^{-19} \text{ C}\right)}$

$= 46 \text{ V}$

Note: For a magnetic field pointing into the page, the electron would move in a clockwise circle in the plane of the page. Of course, a positive particle would move in a counterclockwise circle in the same field.

REF: K/U OBJ: 8.2 LOC: EGV.01 KEY: FOP 16.3, p.632
MSC: SP

84. ANS:
The magnitude of the force is

$$F = Bqv\sin\theta$$
$$= (0.25\ \text{T})\left(1.6 \times 10^{-19}\ \text{C}\right)\left(4.0 \times 10^{6}\ \text{m/s}\right)\sin 90^\circ$$
$$= 1.6 \times 10^{-13}\ \text{N}$$

Using the right-hand rule, the direction of the force is up, towards the top of the page, in the plane of the page.

REF: K/U, C OBJ: 8.2 LOC: EG1.08 KEY: FOP 16.3, p.630
MSC: SP

85. ANS:
(a) $f = \dfrac{c}{\lambda}$

$$= \frac{3.0 \times 10^{8}\ \text{m/s}}{1.5 \times 10^{-2}\ \text{m}}$$
$$= 2.0 \times 10^{10}\ \text{Hz}$$

(b) $\Delta d = v\Delta t$

But, since $v = c$,

$$\Delta t = \frac{\Delta d}{c}$$
$$= \frac{8.0 \times 10^{6}\ \text{m}}{3.0 \times 10^{8}\ \text{m/s}}$$
$$= 2.7 \times 10^{-2}\ \text{s}$$

REF: K/U OBJ: 9.6 LOC: WA1.01 KEY: FOP 16.8, p.652
MSC: SP

86. ANS:

$$f_1 = \frac{c}{\lambda_1}$$
$$= \frac{3.00 \times 10^{8}\ \text{m/s}}{4.00 \times 10^{-7}\ \text{m}}$$
$$= 7.50 \times 10^{14}\ \text{Hz}$$

$$f_2 = \frac{c}{\lambda_2}$$

$$= \frac{3.00 \times 10^8 \text{ m/s}}{7.50 \times 10^{-7} \text{ m}}$$

$$= 4.00 \times 10^{14} \text{ Hz}$$

REF: K/U OBJ: 9.6 LOC: WA1.01 KEY: FOP 16.8, p.652
MSC: P

87. ANS:

$$\lambda = \frac{c}{f}$$

$$= \frac{3.0 \times 10^8 \text{ m/s}}{1 \times 10^{26} \text{ Hz}}$$

$$= 3 \times 10^{-18} \text{ m}$$

REF: K/U OBJ: 9.6 LOC: WA1.01 KEY: FOP 16.8, p.652
MSC: P

88. ANS:

$$\lambda = \frac{c}{f}$$

$$= \frac{3.0 \times 10^8 \text{ m/s}}{60 \text{ Hz}}$$

$$= 5.0 \times 10^6 \text{ m}$$

$$N = \frac{d}{\lambda}$$

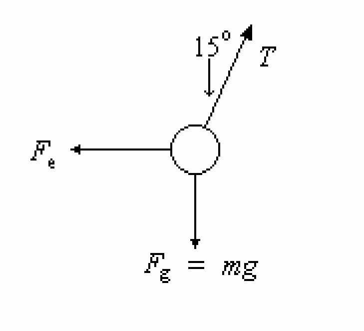
$$= \frac{8.0 \times 10^6 \text{ m/s}}{5.0 \times 10^6 \text{ m}}$$

$$= 1.6 \text{ wavelengths}$$

REF: K/U OBJ: 9.6 LOC: WA1.01 KEY: FOP 16.8, p.652
MSC: P

PROBLEM

89. ANS:
For each sphere, a free body diagram shows



Resolving forces in the *x* and *y* directions

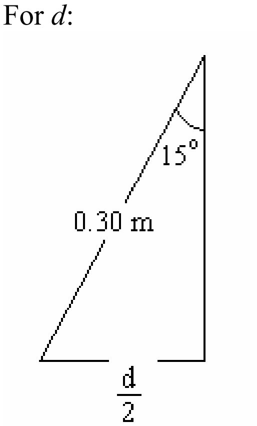
$T\cos 15° = mg$

$T\sin 15° = F_e$

$$\frac{F_e}{mg} = \frac{\sin 15°}{\cos 15°} = \tan 15°$$

$$F_e = mg\tan 15° = \left(2.0 \times 10^{-3}\ \text{kg}\right)\left(9.8\ \text{N/kg}\right)(0.268) = 5.25 \times 10^{-3}\ \text{N}$$

For *d*:



$$\frac{\left(\frac{d}{2}\right)}{0.30\ \text{m}} = \sin 15°$$

$$d = (2)(0.30\ \text{m})(\sin 15°) = 0.155\ \text{m}$$

Then, $F = \frac{kQ_1Q_2}{d^2}$ where $Q_1 = Q_2 = q$

$$q = \sqrt{\frac{Fd^2}{k}}$$

$$= \sqrt{\frac{\left(5.25 \times 10^{-3}\ \text{N}\right)(0.155\ \text{m})^2}{\left(9.0 \times 10^{0}\ \text{N} \cdot \text{m}^2/\text{C}^2\right)}}$$

$$= \sqrt{1.40 \times 10^{-14}\ \text{C}^2}$$

$$= 1.2 \times 10^{-7}\ \text{C}$$

REF: K/U OBJ: 7.2 LOC: EG1.06 KEY: FOP 15.3, p.583
MSC: P

90. ANS:
Since all three charges are in a straight line, we can take the vector nature of force into account by assigning forces to the right as positive. Sphere C has forces acting on it from spheres A and B.

For the force from sphere A:

$$F_1 = k\frac{q_A q_C}{{d_{AC}}^2}$$

$$= \frac{\left(9.0 \times 10^{9}\ \text{N} \cdot \text{m}^2/\text{C}^2\right)\left(4.0 \times 10^{-6}\ \text{C}\right)\left(6.4 \times 10^{-6}\ \text{C}\right)}{(0.30\ \text{m})^2}$$

$$\therefore\ \vec{F}_1 = 2.6\ \text{N [right]}$$

And for the force from sphere B:

$$F_2 = k\frac{q_B q_C}{{d_{BC}}^2}$$

$$= \frac{\left(9.0 \times 10^{9}\ \text{N} \cdot \text{m}^2/\text{C}^2\right)\left(2.5 \times 10^{-1}\ \text{C}\right)\left(6.4 \times 10^{-6}\ \text{C}\right)}{(0.10\ \text{m})^2}$$

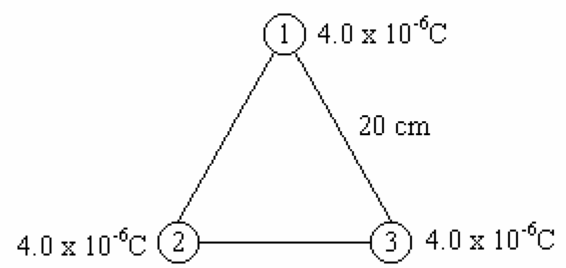
$$\therefore\ \vec{F}_2 = 1.4\ \text{N [left]}$$

The net force acting on sphere C is the sum of $\vec{F}_1$ and $\vec{F}_2$

$$\vec{F}_{net} = \vec{F}_1 + \vec{F}_2$$
$$= 2.6 \text{ N [right]} + 1.4 \text{ N [left]}$$
$$= 1.2 \text{ N [right]}$$

REF: K/U OBJ: 7.2 LOC: EG1.06 KEY: FOP 15.3, p.584
MSC: SP

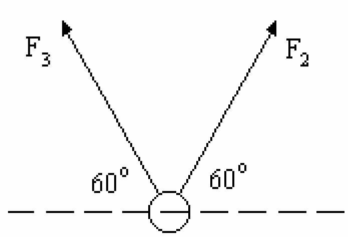
91. ANS:



For the magnitude of each repulsive force,

$$F = \frac{kQ_1Q_2}{d^2}$$
$$= \frac{\left(9.0 \times 10^9 \text{ N} \cdot \text{m}^2/\text{C}^2\right)\left(4.0 \times 10^{-6} \text{ C}\right)^2}{(0.20 \text{ m})^2}$$
$$= 3.6 \text{ N}$$

For sphere 1:



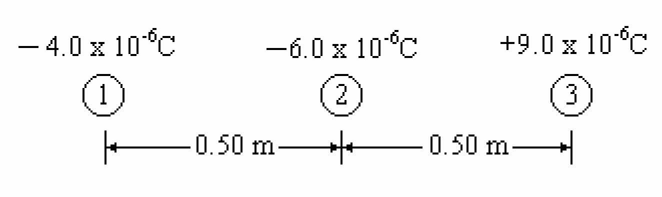
Using components in the *x-y* plane,

$$F_{3_x} = -F_3 \cos 60° = -(3.6 \text{ N})(0.50) = -1.8 \text{ N}$$
$$F_{3_y} = F_3 \sin 60° = (3.6 \text{ N})(0.867) = 3.1 \text{ N}$$
$$F_{2_x} = F_2 \cos 60° = 1.8 \text{ N}$$
$$F_{2_y} = F_2 \sin 60° = 3.1 \text{ N}$$
$$\therefore F_{net_x} = 0 \text{ and } F_{net_y} = 6.2 \text{ N}$$

The net forces on 2 and 3 have the same magnitude and act along in symmetrical outward directions.

REF: K/U OBJ: 7.2 LOC: EG1.06 KEY: FOP 15.3, p.586
MSC: P

92. ANS:



For sphere 1:

$$F_{12} = \frac{kQ_1Q_2}{d_{12}^2}$$

$$= \frac{(9.0 \times 10^9\ \text{N}\cdot\text{m}^2/\text{C}^2)(4.0 \times 10^{-6}\ \text{C})(6.0 \times 10^{-6}\ \text{C})}{(0.50\ \text{m})^2}$$

$$\vec{F}_{12} = 8.64 \times 10^{-1}\ \text{N, or } 0.864\ \text{N [left]}$$

$$F_{13} = \frac{kQ_1Q_3}{d_{13}^2}$$

$$= \frac{(9.0 \times 10^9\ \text{N}\cdot\text{m}^2/\text{C}^2)(4.0 \times 10^{-6}\ \text{C})(9.0 \times 10^{-6}\ \text{C})}{(1.0\ \text{m})^2}$$

$$F_{13} = 3.24 \times 10^{-1}\ \text{N}$$

$$\vec{F}_{13} = 0.324\ \text{N [right]}$$

$$\vec{F}_1 = \vec{F}_{12} + \vec{F}_{13}$$

$$= 0.864\ \text{N [left]} + 0.324\ \text{N [right]}$$

$$= 0.54\ \text{N [left]}$$

For sphere 2:

$$F_{23} = \frac{kQ_2Q_3}{d_{23}{}^2}$$

$$= \frac{\left(9.0 \times 10^9\ \text{N}\cdot\text{m}^2/\text{C}^2\right)\left(6.0 \times 10^{-6}\ \text{C}\right)\left(9.0 \times 10^{-6}\ \text{C}\right)}{(0.50\ \text{m})^2}$$

$$\vec{F}_{23} = 1.944\ \text{N}\ [\text{right}]$$

$$\vec{F}_2 = \vec{F}_{21} + \vec{F}_{23}$$

$$= 0.864\ \text{N}\ [\text{right}] + 1.944\ \text{N}\ [\text{right}]$$

$$= 2.8\ \text{N}\ [\text{right}]$$

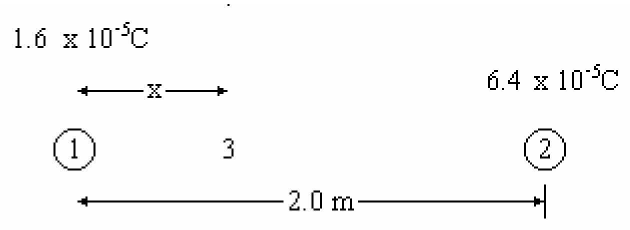
$$\vec{F}_3 = \vec{F}_{31} + \vec{F}_{32}$$

$$= 0.324\ \text{N}\ [\text{left}] + 1.944\ \text{N}\ [\text{left}]$$

$$= 2.3\ \text{N}\ [\text{left}]$$

REF: K/U OBJ: 7.2 LOC: EG1.06 KEY: FOP 15.3, p.586
MSC: P

93. ANS:



The third charge must be situated on a line joining q_1 and q_2, a distance x from q_1, as shown.

For there to be no net force on q_3:

$$F_{13} = F_{23}$$

$$\frac{kQ_1Q_3}{(d_{13})^2} = \frac{kQ_2Q_3}{(d_{23})^2}$$

$$\frac{k\left(1.6 \times 10^{-5}\ \text{C}\right)(Q_3)}{x^2} = \frac{k\left(6.4 \times 10^{-5}\ \text{C}\right)(Q_3)}{(2.0\ \text{m} - x)^2}$$

Omitting units for simplicity and multiplying both sides by 10^5 ,

$$(1.6)(2-x)^2 = 6.4x^2 \qquad \text{(divide by 1.6)}$$

$$4 - 4x + x^2 = 4x^2$$

$$3x^2 + 4x - 4 = 0$$

$$x = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$$

$$= \frac{-4 \pm \sqrt{16 - 4(3)(-4)}}{6}$$

$$= \frac{-4 \pm 8}{6}$$

$$x = \frac{-12}{6} \text{ or } x = \frac{4}{6}$$

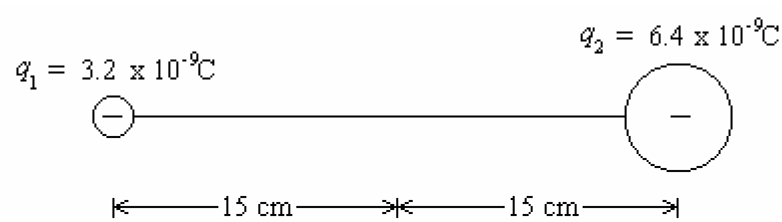
$$x = -2.0 \text{ or } x = 0.67$$

Since $x = -2.0$ is an inadmissible solution, the third charge is located 0.67 m from the 1.6×10^{-5} C charge.

Note: Q_3 divides out of the original equation—we really do not need to know its value or even its sign.

REF: K/U, C OBJ: 7.2 LOC: EG1.06 KEY: FOP 15.3, p.586
MSC: P

94. ANS:



There will be an electric field at the midpoint due to each of the two charges. The net field will be the vector sum of the two separate fields. Calling these fields $\vec{\varepsilon}_1$ and $\vec{\varepsilon}_2$, respectively, we have

$$\vec{\varepsilon}_1 = \frac{kq_1}{d_1^{\,2}}$$

$$= \frac{\left(9.0 \times 10^9 \text{ N} \cdot \text{m}^2/\text{C}^2\right)\left(3.2 \times 10^{-9} \text{ C}\right)}{(0.15 \text{ m})^2}$$

$$= 1.3 \times 10^3 \text{ N/C [left]}$$

Also, $\vec{\varepsilon}_2 = \dfrac{kq_2}{d_2^{\ 2}}$

$$= \frac{\left(9.0 \times 10^9 \text{ N} \cdot \text{m}^2/\text{C}^2\right)\left(6.4 \times 10^{-9} \text{ C}\right)}{(0.15 \text{ m})^2}$$

$$= 2.6 \times 10^3 \text{ N/C [right]}$$

Thus, the net electric field intensity, at the midpoint, is the vector sum of these two fields, which is $\vec{\varepsilon}_{\text{net}} = 1.3 \times 10^3 \text{ N/C [right]}$

REF: K/U OBJ: 7.3 LOC: EG1.06 KEY: FOP 15.4, p.590
MSC: SP

95. ANS:

(a) Since $\varepsilon \propto q$, then $\dfrac{\varepsilon_2}{\varepsilon_1} = \dfrac{q_2}{q_1}$

$$\varepsilon_2 = \varepsilon_1 \left[\frac{q_2}{q_1}\right]$$

$$= \left(1.5 \times 10^2 \text{ N/C}\right)(2)$$

$$= 3.0 \times 10^2 \text{ N/C}$$

(b) Since $\varepsilon \propto q$ only, changing *d* has no effect.

$\therefore\ \varepsilon_2 = \varepsilon_1 = 1.5 \times 10^2 \text{ N/C}$

REF: K/U OBJ: 7.3 LOC: EG1.01 KEY: FOP 15.4, p.591
MSC: SP

96. ANS:

$$\varepsilon_{zx} = \frac{kQ_x}{d_{zx}^{\ 2}}$$

$$= \frac{\left(9.0 \times 10^9 \text{ N} \cdot \text{m}^2/\text{C}^2\right)\left(+5.0 \times 10^{-5} \text{ C}\right)}{(0.75 \text{ m})^2}$$

$$= +8.0 \times 10^5 \text{ N/C}$$

$$\varepsilon_{zy} = \frac{kQ_y}{{d_{zy}}^2}$$

$$= \frac{\left(9.0 \times 10^9\ \text{N} \cdot \text{m}^2/\text{C}^2\right)\left(-1.0 \times 10^{-5}\ \text{C}\right)}{(0.30\ \text{m})^2}$$

$$= -1.0 \times 10^6\ \text{N/C}$$

$$\vec{\varepsilon}_z = \vec{\varepsilon}_{zx} + \vec{\varepsilon}_{zy}\ \text{(right positive)}$$

$$\varepsilon_z = 8.0 \times 10^5\ \text{N/C} - 10.0 \times 10^5\ \text{N/C}$$

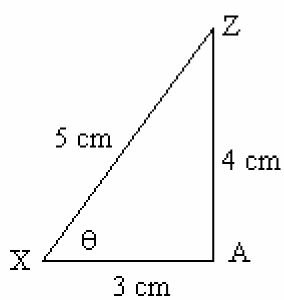
$$= -2.0 \times 10^5\ \text{N/C, or}$$

$$\vec{\varepsilon}_z = 2.0 \times 10^5\ \text{N/C [left]}$$

REF: K/U OBJ: 7.3 LOC: EG1.06 KEY: FOP 15.4, p.592
MSC: P

97. ANS:

$$d_{xz} = \sqrt{(3.0\ \text{cm})^2 + (4.0\ \text{cm})^2} = 5.0\ \text{cm} = d_{yz}$$



$$\theta = \tan^{-1}\frac{4\ \text{cm}}{3\ \text{cm}}$$

$$= \tan^{-1} 1.33$$

$$= 53^\circ$$

At *Z*:

$$\varepsilon_{zx} = \frac{kQ_x}{{d_{zx}}^2}$$

$$= \frac{\left(9.0 \times 10^9 \text{ N} \cdot \text{m}^2/\text{C}^2\right)\left(2.0 \times 10^{-8} \text{ C}\right)}{\left(5.0 \times 10^{-2} \text{ m}\right)^2}$$

$$= 0.72 \times 10^5 \text{ N/C}$$

$$\vec{\varepsilon}_{zx} = 7.2 \times 10^4 \text{ N/C [R53°U]}$$

$$\vec{\varepsilon}_{zy} = 7.2 \times 10^4 \text{ N/C [L53°U]}$$

Taking components:

$$\left(\varepsilon_{zx}\right)_x = \left(7.2 \times 10^4 \text{ N/C}\right)(\cos 53°)$$

$$= 4.3 \times 10^4 \text{ N/C}$$

$$\left(\varepsilon_{zx}\right)_y = \left(7.2 \times 10^4 \text{ N/C}\right)(\sin 53°)$$

$$= 5.75 \times 10^4 \text{ N/C}$$

$$\left(\varepsilon_{zy}\right)_x = -\left(7.2 \times 10^4 \text{ N/C}\right)(\cos 53°)$$

$$= -4.3 \times 10^4 \text{ N/C}$$

$$\left(\varepsilon_{zy}\right)_y = \left(7.2 \times 10^4 \text{ N/C}\right)(\sin 53°)$$

$$= 5.75 \times 10^4 \text{ N/C}$$

$$\therefore \left(\varepsilon_{z\text{net}}\right)_x = 0$$

$$\left(\varepsilon_{z\text{net}}\right)_y = 11.5 \times 10^4 \text{ N/C}$$

$$\vec{\varepsilon}_{z\text{net}} = 1.2 \times 10^5 \text{ N/C [U]}$$

REF: K/U OBJ: 7.3 LOC: EG1.06 KEY: FOP 15.4, p.592
MSC: P

98. ANS:

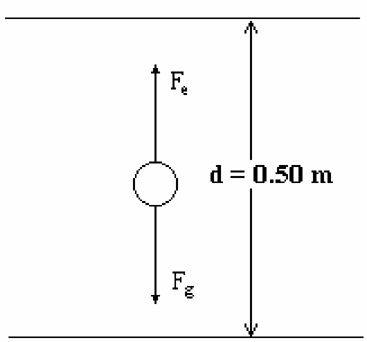
$$Q = Ne$$
$$= \left(5.00 \times 10^{9}\right)\left(1.6 \times 10^{-19}\ \text{C}\right)$$
$$= -8.00 \times 10^{-10}\ \text{C}$$

$$\varepsilon = \frac{kQ}{d^2}$$
$$= \frac{\left(9.0 \times 10^{9}\ \text{N} \cdot \text{m}^2/\text{C}^2\right)\left(-8.00 \times 10^{-10}\ \text{C}\right)}{(5.00\ \text{m})^2}$$
$$= -28.8\ \text{N/C}$$

$$V = \frac{kQ}{r}$$
$$= \frac{\left(9.0 \times 10^{9}\ \text{N} \cdot \text{m}^2/\text{C}^2\right)\left(-8.00 \times 10^{-10}\ \text{C}\right)}{(0.500\ \text{m})}$$
$$= -14.4\ \text{V}$$

REF: K/U OBJ: 7.5 LOC: EG1.06 KEY: FOP 15.6, p.601
MSC: P

99. ANS:



(a) $\varepsilon = \frac{F_e}{q}$

$$= \frac{4.5 \times 10^{-15}\ \text{N}}{6.4 \times 10^{-19}\ \text{C}}$$
$$= 7.0 \times 10^{3}\ \text{N/C}$$

$$V = \varepsilon d$$
$$= \left(7.0 \times 10^{3} \text{ N/C}\right)(0.050\text{m})$$
$$= 3.5 \times 10^{2} \text{ V}$$

(b) $m = \frac{F_g}{g}$
$$= \frac{F_e}{g}$$
$$= \frac{4.5 \times 10^{-15} \text{ N}}{9.8 \text{ N/kg}}$$
$$= 4.6 \times 10^{-16} \text{ kg}$$

REF: K/U OBJ: 7.5 LOC: EG1.06 KEY: FOP 15.6, p.601
MSC: P

100. ANS:
$$F_e = F_g$$
$$= mg$$
$$= \left(4.95 \times 10^{-15} \text{ kg}\right)\left(9.8 \text{ N/kg}\right)$$
$$= 4.85 \times 10^{-14} \text{ N}$$

$$\varepsilon = \frac{V}{d}$$
$$= \frac{510 \text{ V}}{\left(1.0 \times 10^{-2} \text{ m}\right)}$$
$$= 5.10 \times 10^{4} \text{ N/C}$$

But, $\varepsilon = \dfrac{F_e}{q}$

$$q = \frac{F_e}{\varepsilon}$$

$$= \frac{4.85 \times 10^{-14}\ \text{N}}{5.10 \times 10^{4}\ \text{N/C}}$$

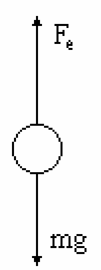
$$= 9.5 \times 10^{-19}\ \text{C}$$

$$= 6e$$

Since the upper plate is positive, the charge must be negative due to an excess of electrons.

REF: K/U OBJ: 7.5 LOC: EG1.06 KEY: FOP 15.6, p.601
MSC: P

101. ANS:



$$\varepsilon = \frac{F_e}{q}$$

$$\therefore\ F_e = q\varepsilon = mg$$

$$q = \frac{mg}{\varepsilon}$$

$$= \frac{\left(2.0 \times 10^{-15}\ \text{kg}\right)\left(9.8\ \text{N/kg}\right)}{(100\ \text{N/C})}$$

$$= 1.96 \times 10^{-16}\ \text{C}$$

$$= 1.2 \times 10^{3}\ e$$

REF: K/U OBJ: 7.5 LOC: EG1.06 KEY: FOP 15.6, p.601
MSC: P

102. ANS:

At a distance $r_1 = 0.25$ m,

$$E_{e1} = k\frac{q_1 q_2}{r_1}$$

$$= \frac{\left(9.0 \times 10^9\ \text{N}\cdot\text{m}^2/\text{C}^2\right)\left(5.0 \times 10^{-6}\ \text{C}\right)\left(2.0 \times 10^{-9}\ \text{C}\right)}{(0.25\ \text{m})}$$

$$= 3.6 \times 10^{-4}\ \text{J}$$

At a distance $r_2 = 0.50$ m,

$$E_{e2} = k\frac{q_1 q_2}{r_2}$$

$$= 1.8 \times 10^{-4}\ \text{J}$$

Therefore, in moving from r_1 to r_2,

$$\Delta E_e = E_{e2} - E_{e1}$$

$$= 1.8 \times 10^{-4}\ \text{J} - 3.6 \times 10^{-4}\ \text{J}$$

$$= -1.8 \times 10^{-4}\ \text{J}$$

But, this loss in electric potential energy is gained by the pith ball as kinetic energy.

$$\Delta E_k = 1.8 \times 10^{-4}\ \text{J} = \frac{1}{2}mv^2$$

$$v = \sqrt{\frac{2\Delta E_k}{m}}$$

$$= \sqrt{\frac{2\left(1.8 \times 10^{-4}\ \text{J}\right)}{1.0 \times 10^{-5}\ \text{kg}}}$$

$$= 6.0\ \text{m/s}$$

When the electric field in which the charged particle is moving is a uniform electric field, its motion is much simpler. In a uniform electric field

$$\vec{F}_e = q\vec{\varepsilon} = \text{constant}$$

Therefore, $\vec{a} = \frac{\vec{F}_e}{m} = \text{constant, also.}$

Thus, the charged particle moves with uniform acceleration. This will be the case for small charged particles (such as ions, electrons, and protons) where gravitational effects are negligible and they are moving between two parallel plates in a vacuum. Besides, the work done by a constant force is just the product of the force and the displacement. In a parallel plate apparatus, whose separation is *d*, the work done in moving a charge *q* from one plate to the other is

$$W = \vec{F}_e \cdot \vec{d}$$

$$= \varepsilon q d \quad \text{since } \vec{\varepsilon} \text{ and } \vec{d} \text{ are in the same direction}$$

$$= \frac{V}{d} q d$$

$$= Vq$$

This amount of work is equal in magnitude to the change in electric potential energy and also the change in kinetic energy of the particle as it moves from one plate to the other.

REF: K/U OBJ: 7.4 LOC: EG1.05 KEY: FOP 15.7, p.603
MSC: SP

103. ANS:

$$E_e = \frac{kq_1q_2}{r}$$

$$= \frac{\left(9.0 \times 10^9 \text{ N} \cdot \text{m}^2/\text{C}^2\right)\left(1.6 \times 10^{-19} \text{ C}\right)^2}{10^{-12} \text{ m}}$$

$$= 2.3 \times 10^{-16} \text{ J}$$

$$E_{\text{total}} = E_k + E_e = 2.3 \times 10^{-16} \text{ J} \left(\text{since } E_k = 0\right)$$

$$E'_{\text{total}} = E'_k + E'_k + E'_e$$

$$= 2\left(\frac{1}{2}mv^2\right) \left(\text{since } E'_e = 0\right)$$

But $E'_{\text{total}} = E_{\text{total}} = 2.3 \times 10^{-16} \text{ J}$

$$v = \sqrt{\frac{2E_k}{m}}$$
$$= \sqrt{\frac{E_{total}}{m}}$$
$$= \sqrt{\frac{2.3 \times 10^{-16}\ \text{J}}{9.1 \times 10^{-31}\ \text{kg}}}$$
$$= 1.6 \times 10^{7}\ \text{m/s}$$

REF: K/U OBJ: 7.4 LOC: EG1.05 KEY: FOP 15.7, p.605
MSC: P

104. ANS:

(a) $F = \dfrac{kQ_1Q_2}{d^2}$

$$= \frac{\left(9.0 \times 10^{9}\ \text{N}\cdot\text{m}^2/\text{C}^2\right)\left(1.6 \times 10^{-19}\ \text{C}^2\right)}{\left(5.3 \times 10^{-11}\ \text{m}\right)^2}$$

$$= 8.2 \times 10^{-8}\ \text{N}$$

(b) $F = \dfrac{Gm_1m_2}{d^2}$

$$= \frac{\left(6.67 \times 10^{-11}\ \text{N}\cdot\text{m}^2/\text{kg}^2\right)\left(1.67 \times 10^{-27}\ \text{kg}\right)\left(9.1 \times 10^{-31}\ \text{kg}\right)}{\left(5.3 \times 10^{-11}\ \text{m}\right)^2}$$

$$= 3.6 \times 10^{-47}\ \text{N}$$

(c) The electrostatic force is responsible for the electron's centripetal motion around the proton.

(d) $F = \frac{mv^2}{r}$

$$v = \sqrt{\frac{Fr}{m}}$$
$$= \sqrt{\frac{\left(8.2 \times 10^{-8}\ \text{N}\right)\left(5.3 \times 10^{-11}\ \text{m}\right)}{9.1 \times 10^{-31}\ \text{kg}}}$$
$$= \sqrt{4.78 \times 10^{12}\ (\text{m/s})^2}$$
$$= 2.2 \times 10^{6}\ \text{m/s}$$

$$T = \frac{2\pi r}{v}$$
$$= \frac{2\pi\left(5.3 \times 10^{-11}\ \text{m}\right)}{2.2 \times 10^{6}\ \text{m/s}}$$
$$= 1.5 \times 10^{-16}\ \text{s}$$

REF: K/U, C OBJ: 7.2 LOC: EG1.03 KEY: FOP 15.9, p.612
MSC: P

105. ANS:

Let the original opposite charges be $+Q_a$ and $-Q_b$, and assume $Q_a > Q_b > 0$. The final equal charges will be $Q_c = \frac{1}{2}(Q_a - Q_b)$, which our assumption makes positive.

(a) $F_2 = \frac{kQ_c^2}{d^2}$

$$Q_c = \sqrt{\frac{F_2 d^2}{k}}$$
$$= \sqrt{\frac{\left(1.0 \times 10^{-5}\ \text{N}\right)(0.30\ \text{m})^2}{9.0 \times 10^{9}\ \text{N} \cdot \text{m}^2/\text{C}^2}}$$
$$= 1.0 \times 10^{-8}\ \text{C}$$

(b) Conservation of charge gives:

$$2Q_c = Q_a - Q_b$$

$$Q_b = Q_a - 2Q_c$$

$$= Q_a - 2.0 \times 10^{-8}\ \text{C}$$

Omitting units for simplicity:

$$F_1 = \frac{kQ_a\left(Q_a - 2.0 \times 10^{-8}\right)}{d^2}$$

$$Q_a{}^2 - 2.0 \times 10^{-8}\ Q_a = \frac{F_1 d^2}{k_2}$$

$$= \frac{\left(8.0 \times 10^{-5}\right)(0.30)^2}{9.0 \times 10^9}$$

$$Q_a{}^2 - 2.0 \times 10^{-8}\ Q_a - 8.0 \times 10^{-16} = 0$$

$$\left(Q_a - 4.0 \times 10^{-8}\right)\left(Q_a + 2.0 \times 10^{-8}\right) = 0$$

$$Q_a = 4.0 \times 10^{-8}, \text{ or } -2.0 \times 10^{-8}$$

We assumed that $Q_a < 0$.

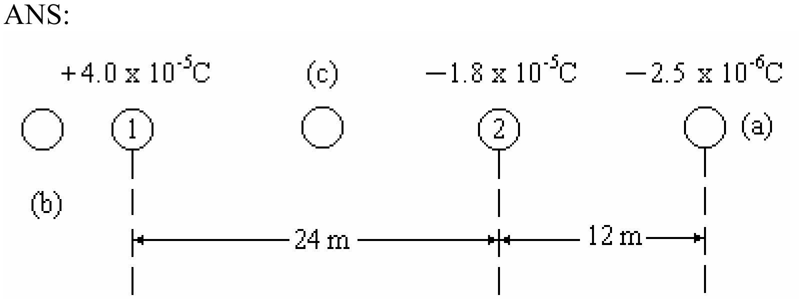
Therefore, $Q_a = 4.0 \times 10^{-8}\ \text{C}$

$-Q_b = 2.0 \times 10^{-8}\ \text{C}$

Note: All of the signs could be reversed.

REF: K/U OBJ: 7.2 LOC: EG1.03 KEY: FOP 15.9, p.613
MSC: P

106. ANS:



(a) $F_1 = \dfrac{kQ_1Q_3}{d_{13}^{\ 2}}$

$$= \frac{\left(9.0 \times 10^9 \text{ N} \cdot \text{m}^2/\text{C}^2\right)\left(4.0 \times 10^{-5} \text{ C}\right)\left(2.5 \times 10^{-6} \text{ C}\right)}{(0.36 \text{ m})^2}$$

$\vec{F}_1 = 6.9$ N [left]

$F_2 = \dfrac{kQ_2Q_3}{d_{23}^{\ 2}}$

$$= \frac{\left(9.0 \times 10^9 \text{ N} \cdot \text{m}^2/\text{C}^2\right)\left(1.8 \times 10^{-5} \text{ C}\right)\left(2.5 \times 10^{-6} \text{ C}\right)}{(0.12 \text{ m})^2}$$

$\vec{F}_2 = 28.1$ N [right]

$\therefore \vec{F}_1 = (28.1 - 6.9)$ N [right]

≈ 21 N [right]

(b) $F_1 = \dfrac{kQ_1Q_3}{d_{13}^{\ 2}}$

$$= \frac{\left(9.0 \times 10^9 \text{ N} \cdot \text{m}^2/\text{C}^2\right)\left(4.0 \times 10^{-5} \text{ C}\right)\left(2.5 \times 10^{-6} \text{ C}\right)}{(0.12 \text{ m})^2}$$

$\vec{F}_1 = 62.5$ N [right]

$F_2 = \dfrac{kQ_2Q_3}{d_{23}^{\ 2}}$

$$= \frac{\left(9.0 \times 10^9 \text{ N} \cdot \text{m}^2/kg^2\right)\left(1.8 \times 10^{-5} \text{ C}\right)\left(2.5 \times 10^{-6} \text{ C}\right)}{(0.36 \text{ m})^2}$$

$\vec{F}_2 = 3.1$ N [left]

$\therefore F_{net} = (62.5 - 3.1)$ N [right]

≈ 59 N [right]

(c) $F_1 = \dfrac{kQ_1Q_3}{d_{13}{}^2}$

$\vec{F}_1 = 62.5$ N [left]

$F_2 = \dfrac{kQ_2Q_3}{d_{23}{}^2}$

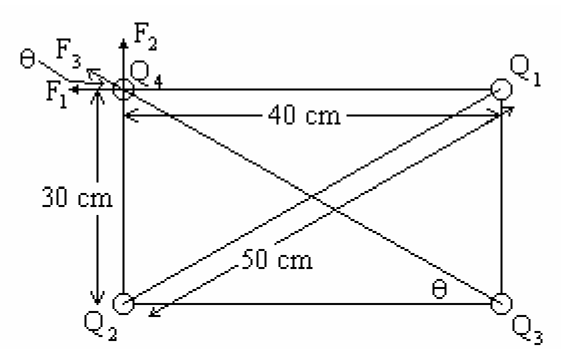
$\vec{F}_2 = 28.1$ N [left]

$\therefore\ \vec{F}_{net} = (62.5 + 28.1)$ N [left]

≈ 91 N [left]

REF: K/U OBJ: 7.2 LOC: EG1.06 KEY: FOP 15.9, p.613
MSC: P

107. ANS:



For the diagonal,

$$d = \sqrt{(40\text{ cm})^2 + (30\text{ cm})^2}$$
$$= 50\text{ cm}$$

$$\sin\theta = \frac{30\text{ cm}}{50\text{ cm}}$$
$$= 0.6$$
$$\theta = 37^\circ$$

Each charge experiences three forces; 1 along each side, and 1 along the diagonal.

For the force on Q_4:

$$F_1 = \frac{kQ_1Q_4}{d_{14}{}^2}$$

$$= \frac{\left(9.0 \times 10^9 \text{ N} \cdot \text{m}^2/\text{C}^2\right)\left(1.2 \times 10^{-3} \text{ C}\right)^2}{(0.40 \text{ m})^2}$$

$$= 8.1 \times 10^4 \text{ N}$$

$$F_2 = \frac{kQ_2Q_4}{d_{24}{}^2}$$

$$= \frac{\left(9.0 \times 10^9 \text{ N} \cdot \text{m}^2/\text{C}^2\right)\left(1.2 \times 10^{-3} \text{ C}\right)^2}{(0.30 \text{ m})^2}$$

$$= 1.44 \times 10^5 \text{ N}$$

$$F_3 = \frac{kQ_3Q_4}{d_{34}{}^2}$$

$$= \frac{\left(9.0 \times 10^9 \text{ N} \cdot \text{m}^2/\text{C}^2\right)\left(1.2 \times 10^{-3} \text{ C}\right)^2}{(0.50 \text{ m})^2}$$

$$= 5.2 \times 10^4 \text{ N}$$

Therefore, $\vec{F}_{\text{net}} = \vec{F}_1 + \vec{F}_2 + \vec{F}_3$.

Taking the components in the *x*-*y* plane:

	x	y
F_1	-8.1×10^4 N	0
F_2	0	1.44×10^5 N
F_3	$\left(-5.2 \times 10^4\right)(\cos 37°)$ N	$\left(5.2 \times 10^4\right)(\sin 37°)$ N
	$= -4.2 \times 10^4$ N	$= 3.1 \times 10^4$ N
F_{net}	-12.3×10^4 N	17.5×10^4 N

$$\left|F_{\text{net}}\right| = \sqrt{\left|F_x\right|^2 + \left|F_y\right|^2}$$
$$= \sqrt{\left(-1.23 \times 10^5 \text{ N}\right)^2 + \left(1.75 \times 10^5 \text{ N}\right)^2}$$
$$= 2.1 \times 10^5 \text{ N}$$

$$\phi = \tan^{-1} \frac{\left|F_y\right|}{\left|F_x\right|}$$
$$= \tan^{-1} \frac{1.75 \times 10^5 \text{ N}}{1.23 \times 10^5 \text{ N}}$$
$$= \tan^{-1} 1.42$$
$$= 55°$$

$\therefore\ \vec{F}_{\text{net}} = 2.1 \times 10^5 \text{ N } [\text{left } 55° \text{ up}]$ and the force is symmetrically the same at each of the other three corners.

$\varepsilon = \frac{F}{q} = 0$ at the centre, since the forces due to each of the four charges are equal and opposite, in pairs, so that the net force is 0.

$$V = \frac{kQ}{r}$$
$$= \frac{\left(9.0 \times 10^9 \text{ N} \cdot \text{m}^2/\text{C}^2\right)\left(1.2 \times 10^{-3} \text{ C}\right)}{0.25 \text{ m}}$$
$$= 4.32 \times 10^7 \text{ V, for each charge}$$

$$\therefore\ V_{\text{total}} = (4)\left(4.32 \times 10^7 \text{ V}\right)$$
$$= 1.7 \times 10^8 \text{ V}$$

REF: K/U OBJ: 7.3, 7.4 LOC: EG1.06 KEY: FOP 15.9, p.613
MSC: P

108. ANS:

$$V_2 = \frac{kQ}{r_2}$$
$$= \frac{\left(9.0 \times 10^7 \ \text{N} \cdot \text{m}^2/\text{C}^2\right)\left(3.2 \times 10^{-3} \ \text{C}\right)}{0.40 \ \text{m}}$$
$$= 7.2 \times 10^7 \ \text{V}$$

$$V_1 = \frac{kQ}{r_1}$$
$$= \frac{\left(9.0 \times 10^9 \ \text{N} \cdot \text{m}^2/\text{C}^2\right)\left(3.2 \times 10^{-3} \ \text{C}\right)}{1.00 \ \text{m}}$$
$$= 2.9 \times 10^7 \ \text{V}$$

$$W = q\Delta V$$
$$= q\left(V_2 - V_1\right)$$
$$= \left(1.0 \times 10^{-6} \ \text{C}\right)\left(4.3 \times 10^7 \ \text{V}\right)$$
$$= 4.3 \times 10^1 \ \text{J, or 43 J}$$

REF: K/U OBJ: 7.4 LOC: EG1.05 KEY: FOP 15.9, p.614
MSC: P

109. ANS:

$$F_e = F_g$$
$$= mg$$
$$= \left(2.6 \times 10^{-15} \ \text{kg}\right)\left(9.8 \ \text{N/kg}\right)$$
$$= 2.55 \times 10^{-14} \ \text{N}$$

$$q = \frac{F_e}{\varepsilon}$$
$$= \frac{2.55 \times 10^{-14} \ \text{N}}{5.4 \times 10^4 \ \text{N/C}}$$
$$= 4.7 \times 10^{-19} \ \text{C}$$

$$\varepsilon = \frac{V}{d}$$

$$= \frac{270 \text{ V}}{5.0 \times 10^{-3} \text{ m}}$$

$$= 5.4 \times 10^{4} \text{ N/C}$$

$$N = \frac{q}{e}$$

$$= \frac{4.7 \times 10^{-19} \text{ C}}{1.6 \times 10^{-19} \text{ C}}$$

$$\approx 3$$

We cannot tell if excess or deficit unless we know which plate is positive.

REF: K/U OBJ: 7.5 LOC: EG1.06 KEY: FOP 15.9, p.614
MSC: P

110. ANS:

$$F_e = F_g$$

$$= mg$$

$$= \left(1.0 \times 10^{-4} \text{ kg}\right)\left(9.8 \text{ N/kg}\right)$$

$$= 9.8 \times 10^{-4} \text{ N}$$

$$\varepsilon = \frac{F_e}{q}$$

$$= \frac{9.8 \times 10^{-4} \text{ N}}{5.0 \times 10^{-6} \text{ C}}$$

$$= 1.96 \times 10^{2} \text{ N/C}$$

$$\therefore\ V = \varepsilon d$$

$$= \left(1.96 \times 10^{2} \text{ N/C}\right)(0.25 \text{ m})$$

$$= 49 \text{ V}$$

REF: K/U OBJ: 7.5 LOC: EG1.06 KEY: FOP 15.9, p.614
MSC: P

111. ANS:

$$Q = Ne$$
$$= \left(10^{12}\right)\left(-1.6 \times 10^{-19}\ \text{C}\right)$$
$$= -1.6 \times 10^{-7}\ \text{C}$$

$$V = \frac{kQ}{r}$$
$$= \frac{\left(9.0 \times 10^{9}\ \text{N} \cdot \text{m}^2/\text{C}^2\right)\left(-1.6 \times 10^{-7}\ \text{C}\right)}{(0.40\ \text{m})}$$
$$= -3.6 \times 10^{3}\ \text{V}$$

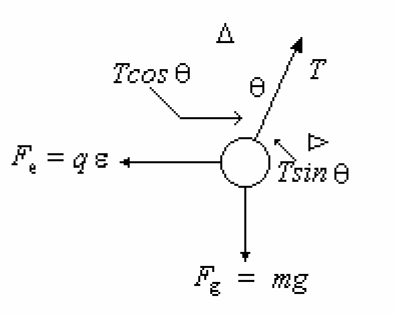
$$\varepsilon = \frac{kQ}{r^2}$$
$$= \frac{\left(9.0 \times 10^{9}\ \text{N} \cdot \text{m}^2/\text{C}^2\right)\left(1.6 \times 10^{-7}\ \text{C}\right)}{(0.40\ \text{m})^2}$$
$$\vec{\varepsilon} = 9.0 \times 10^{3}\ \text{N/C}\ [\text{toward the sphere}]$$

REF: K/U OBJ: 7.5 LOC: EG1.01 KEY: FOP 15.9, p.614
MSC: P

112. ANS:

(a) $\varepsilon = \frac{V}{d}$
$$= \frac{420\ \text{V}}{(0.10\ \text{m})}$$
$$= 4.2 \times 10^{3}\ \text{N/C}$$

(b) Drawing a free body diagram of the ball:

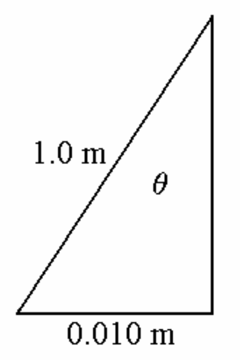


Resolving T into horizontal and vertical components:

$T \cos \theta = mg$

$T \sin \theta = q\varepsilon$

For θ:



$\theta = \sin^{-1} \frac{0.010 \text{ m}}{1.0 \text{ m}}$

$= \sin^{-1} 0.010$

$= 0.57°$

$\therefore \cos \theta = 0.9999$

Then, $T\,(0.9999) = \left(3.0 \times 10^{-4} \text{ kg}\right)\left(9.8 \text{ N/kg}\right)$

$T = 2.94 \times 10^{-3} \text{ N, or } 2.9 \times 10^{-3} \text{ N}$

(c) $F_e = T \sin \theta$

$= \left(2.94 \times 10^{-3} \text{ N}\right)(0.01)$

$= 2.94 \times 10^{-5} \text{ N, or } 2.9 \times 10^{-5} \text{ N}$

(d) $q = \frac{F_e}{\varepsilon}$

$= \frac{2.94 \times 10^{-5} \text{ N}}{4.2 \times 10^{3} \text{ N/C}}$

$= 7.0 \times 10^{-9} \text{ C}$

REF: K/U OBJ: 7.3 LOC: EG1.06 KEY: FOP 15.9, p.614
MSC: P

113. ANS:

$$\begin{aligned} W &= qV \\ &= \Delta E_k \\ &= E_k' - E_k \end{aligned}$$

$$\begin{aligned} E_k' &= \frac{1}{2} m v'^2 \\ &= \frac{1}{2} \left(9.1 \times 10^{-31} \text{ kg}\right)\left(1.0 \times 10^{6} \text{ m/s}\right)^2 \\ &= 4.55 \times 10^{-19} \text{ J} \end{aligned}$$

$$\begin{aligned} E_k &= \frac{1}{2} m v^2 \\ &= \frac{1}{2} \left(9.1 \times 10^{-31} \text{ kg}\right)\left(5.0 \times 10^{6} \text{ m/s}\right)^2 \\ &= 1.14 \times 10^{-17} \text{ J} \end{aligned}$$

$$\begin{aligned} \Delta E_k &= 0.05 \times 10^{-17} \text{ J} - 1.14 \, x \, 10^{-17} \text{ J} \\ &= -1.09 \times 10^{-17} \text{ J} \end{aligned}$$

$$\begin{aligned} V &= \left| \frac{\Delta E_k}{q} \right| \\ &= \frac{1.09 \times 10^{-17} \text{ J}}{1.6 \times 10^{-19} \text{ C}} \\ &= 68 \text{ V} \end{aligned}$$

REF: K/U OBJ: 7.6 LOC: EG1.05 KEY: FOP 15.9, p.615
MSC: P

114. ANS:

(a) $\frac{1}{2}mv^2 = qV$

$$V = \sqrt{\frac{2qV}{m}}$$

$$= \sqrt{\frac{(2)\left(1.6 \times 10^{-19}\ \text{C}\right)(300\ \text{V})}{9.1 \times 10^{-31}\ \text{kg}}}$$

$$= \sqrt{1.05 \times 10^{14}\ (\text{m/s})^2}$$

$$= 1.02 \times 10^{7}\ \text{m/s, or } 1.0 \times 10^{7}\ \text{m/s}$$

(b) Since plates W and Y are connected together, there is no field between them, so the charge drifts with a constant speed and drifts through hole Y at 1.0×10^7 m/s.

From potential energy considerations,
$\Delta E_k = 0, \therefore \Delta V = 0$

(c) For the potential difference required to "stop" the electron,
$\frac{1}{2}mv^2 = qV$

$$V = \frac{mv^2}{2q}$$

$$= \frac{\left(9.1 \times 10^{-31}\ \text{kg}\right)\left(1.05 \times 10^{14}\ (\text{m/s})^2\right)}{2\left(1.6 \times 10^{-19}\ \text{C}\right)}$$

$$= 2.99 \times 10^{2}\ \text{V, or } 300\ \text{V}$$

Therefore, the point between Y and Z where the electron stops is given by

$$\frac{\Delta d}{4\ \text{cm}} = \frac{300\ \text{V}}{500\ \text{V}}$$

$$\Delta d = 2.4\ \text{cm}$$

Therefore, the electron is 1.6 cm from Z when it stops.

(d) The path is reversible, so that the electron arrives back at X with $v = 0$ m/s. (This follows directly from $\Delta v = 0$, therefore, $\Delta E_k = 0$.)

REF: K/U OBJ: 7.6 LOC: EG1.05 KEY: FOP 15.9, p.615
MSC: P

115. ANS:

$$E_k = 2\left(\frac{1}{2}mv^2\right)$$

$$= \left(6.6 \times 10^{-27} \text{ kg}\right)\left(3.0 \times 10^{6} \text{ m/s}\right)^2$$

$$= 5.94 \times 10^{-14} \text{ J}$$

At minimum separation, $\Delta E_e = -E_k$

$$= 5.94 \times 10^{-14} \text{ J}$$

But $E_e = \dfrac{kQ_1Q_2}{d}$

Then, $d = \dfrac{kQ_1Q_2}{E_e}$

$$= \frac{\left(9.0 \times 10^{9} \text{ N}\cdot\text{m}^2/\text{C}^2\right)\left(3.2 \times 10^{-19} \text{ C}\right)^2}{5.94 \times 10^{-14} \text{ J}}$$

$$= 1.55 \times 10^{-14} \text{ m, or } 1.6 \times 10^{-14} \text{ m}$$

REF: K/U OBJ: 7.6 LOC: EG1.05 KEY: FOP 15.9, p.615
MSC: P

116. ANS:

(a) For the time the electron takes to move through the apparatus:

$$\Delta t = \frac{\Delta d_h}{v_h}$$

$$= \frac{0.10 \text{ m}}{8.0 \times 10^{7} \text{ m/s}}$$

$$= 1.25 \times 10^{-9} \text{ s}$$

For its vertical acceleration:

$$a_v = \frac{F_v}{m} \qquad \text{where } F_v = q\varepsilon = q\frac{V}{d}$$

$$= \frac{qV}{md}$$

$$= \frac{\left(1.6 \times 10^{-19}\ \text{C}\right)\left(6.0 \times 10^{2}\ \text{V}\right)}{\left(9.1 \times 10^{-31}\ \text{kg}\right)\left(2.0 \times 10^{-2}\ \text{m}\right)}$$

$$= 5.27 \times 10^{15}\ \text{m/s}^2$$

$$\Delta d_v = \frac{1}{2} a_v (\Delta t)^2$$

$$= \frac{1}{2}\left(5.27 \times 10^{15}\ \text{m/s}^2\right)(1.25 \times 10^{-9}\ \text{s})^2$$

$$= 4.1 \times 10^{-3}\ \text{m, or } 0.41\ \text{cm}$$

(b) For its vertical velocity:

$$v_v = a_v \Delta t$$

$$= \left(5.27 \times 10^{15}\ \text{m/s}^2\right)\left(1.25 \times 10^{-9}\ \text{s}\right)$$

$$= 6.6 \times 10^{6}\ \text{m/s}$$

Also, $v_h = 8.0 \times 10^{7}\ \text{m/s}$

Adding, vectorially, to find resultant velocity,

$$v = \sqrt{v_v{}^2 + v_v{}^2}$$

$$= \sqrt{\left(8.0 \times 10^{7}\ \text{m/s}\right)^2 + \left(6.6 \times 10^{6}\ \text{m/s}\right)^2}$$

$$= 8.03 \times 10^{7}\ \text{m/s}$$

$$\theta = \tan^{-1}\frac{v_v}{v_h}$$

$$= \tan^{-1}\frac{6.6 \times 10^6 \text{ m/s}}{8.0 \times 10^7 \text{ m/s}}$$

$$= \tan^{-1} 0.0825$$

$$= 4.72°$$

$$\therefore \vec{v} = 8.0 \times 10^7 \text{ m/s [right 4.7° down]}$$

REF: K/U OBJ: 7.6 LOC: EG1.01 KEY: FOP 15.9, p.616
MSC: P

117. ANS:
For the magnetic field created by the current in the wire, at a distance of 10 cm:

$$B = \mu_0\left(\frac{I}{2\pi r}\right)$$

$$= \frac{\left(4\pi \times 10^{-7} \text{ T}\cdot\text{m/A}\right)(20 \text{ A})}{(2\pi)\left(1.0 \times 10^{-1} \text{ m}\right)}$$

$$= 4.0 \times 10^{-5} \text{ T}$$

Therefore, the force on the electron moving in this field is:

$$F = qvB\sin\theta$$

$$= \left(1.6 \times 10^{-19} \text{ C}\right)\left(5.0 \times 10^6 \text{ m/s}\right)\left(4.0 \times 10^{-5} \text{ T}\right)(\sin 90°)$$

$$\vec{F} = 3.2 \times 10^{-17} \text{ N [horizontally, toward the wire]}$$

According to the right-hand rule.
The force will increase as the electron moves toward the conductor.

REF: K/U OBJ: 8.2, 8.4 LOC: EG1.08 KEY: FOP 16.11, p.669
MSC: P

118. ANS:
The magnetic field of the solenoid is

$$B = \mu_0\left(\frac{NI}{L}\right)$$

$$= \frac{\left(4\pi \times 10^{-7}\ \text{T}\cdot\text{m/A}\right)(100)(20\ \text{A})}{\left(1.5 \times 10^{-1}\ \text{m}\right)}$$

$$= 1.68 \times 10^{-2}\ \text{T}$$

To balance, force on XY must be:

$$F = mg$$

$$= \left(1.8 \times 10^{-5}\ \text{kg}\right)\left(9.8\ \text{N/kg}\right)$$

$$= 1.76 \times 10^{-4}\ \text{N}$$

Then, the current in the conductor XY is:

$$I = \frac{F}{Bl\sin\theta}$$

$$= \frac{\left(1.76 \times 10^{-4}\ \text{N}\right)}{\left(1.68 \times 10^{-2}\ \text{T}\right)\left(1.5 \times 10^{-2}\ \text{m}\right)(\sin 90^\circ)}$$

$$= 7.0 \times 10^{-1}\ \text{A, or } 0.70\ \text{A}$$

(There is no force on WX and YZ.)

REF: K/U, MC OBJ: 8.4 LOC: EG1.08 KEY: FOP 16.11, p.669
MSC: P

119. ANS:

To balance, the upward magnetic force on a one metre length of wire must be:

$$F_g = mg$$

$$= \left(1.50 \times 10^{-1}\ \text{kg/m}\right)\left(9.8\ \text{N/kg}\right)$$

$$= 1.47\ \text{N/m}$$

Therefore, the magnetic field strength at its location is:

$$B = \frac{F}{Il\sin\theta}$$

$$= \frac{1.47\ \text{N}}{(40\ \text{A})(1.0\ \text{m})(\sin 90°)}$$

$$= 3.68 \times 10^{-2}\ \text{T}$$

Then, the current required in the bottom wire to produce this magnetic field is:

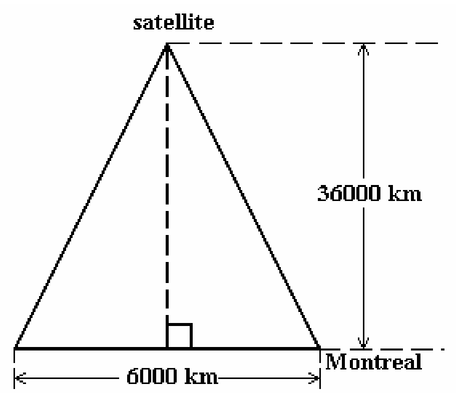
$$I = \frac{2\pi rB}{\mu_0}$$

$$= \frac{(2\pi)\left(4.0 \times 10^{-2}\ \text{m}\right)\left(3.68 \times 10^{-2}\ \text{T}\right)}{\left(4\pi \times 10^{-7}\ \text{T}\cdot\text{m/A}\right)}$$

$$= 7.4 \times 10^{3}\ \text{A}$$

REF: K/U OBJ: 8.4 LOC: EG1.08 KEY: FOP 16.11, p.670
MSC: P

120. ANS:



$$\text{Distance travelled by microwave signal} = 2\sqrt{(3000\ \text{km})^2 + (36\ 000\ \text{km})^2}$$

$$= 2\sqrt{1305 \times 10^{6}\ \text{km}^2}$$

$$= 7.22 \times 10^{4}\ \text{km}$$

Therefore, the time delay is:

$$\Delta t = \frac{d}{c}$$

$$= \frac{7.22 \times 10^7 \text{ m}}{3.0 \times 10^8 \text{ m/s}}$$

$$= 0.24 \text{ s}$$

(This solution ignores Earth’s curvature, the local distance in Montreal, and any electronic time delay in transmission.)

REF: K/U, MC OBJ: 9.6 LOC: WA1.01 KEY: FOP 16.11, p.671
MSC: P

121. ANS:

(a) $\lambda_1 = \frac{c}{f_1}$

$$= \frac{3.0 \times 10^8 \text{ m/s}}{3.0 \times 10^4 \text{ Hz}}$$

$$= 1.0 \times 10^4 \text{ m, or } 10\,000 \text{ m}$$

$$\lambda_2 = \frac{c}{f_2}$$

$$= \frac{3.0 \times 10^8 \text{ m/s}}{4.5 \times 10^4 \text{ Hz}}$$

$$= 6.7 \times 10^3 \text{ m, or } 6700 \text{ m}$$

(b) $\lambda_1 = \frac{v}{f_1}$

$$= \frac{340 \text{ m/s}}{3.0 \times 10^4 \text{ Hz}}$$

$$= 1.1 \times 10^{-2} \text{ m, or } 1.1 \text{ cm}$$

$$\lambda_2 = \frac{v}{f_2}$$

$$= \frac{340 \text{ m/s}}{4.5 \times 10^{4} \text{ Hz}}$$

$$= 7.6 \times 10^{-3} \text{ m, or } 0.76 \text{ cm}$$

REF: K/U, MC OBJ: 9.6 LOC: WA1.01 KEY: FOP 16.11, p.671
MSC: P

122. ANS:

$$v = \frac{rBq}{m}$$

$$= \frac{\left(8.0 \times 10^{-2} \text{ m}\right)(1.5 \text{ T})\left(1.6 \times 10^{-19} \text{ C}\right)}{\left(1.67 \times 10^{-27} \text{ kg}\right)}$$

$$= 1.14 \times 10^{7} \text{ m/s, or } 1.1 \times 10^{7} \text{ m/s}$$

$$qV = \frac{1}{2}mv^{2}$$

$$V = \frac{mv^{2}}{2q}$$

$$= \frac{\left(1.67 \times 10^{-27} \text{ kg}\right)\left(1.14 \times 10^{7} \text{ m/s}\right)^{2}}{(2)\left(1.6 \times 10^{-19} \text{ C}\right)}$$

$$= 6.9 \times 10^{5} \text{ V}$$

REF: K/U OBJ: 8.2 LOC: EG1.01 KEY: FOP 16.3, p.633
MSC: P

123. ANS:

$$F = mg$$

$$= \left(1.5 \times 10^{-2} \text{ kg}\right)\left(9.8 \text{ N/kg}\right)$$

$$= 1.47 \times 10^{-1} \text{ N}$$

$F = BlI \sin \theta$

$$I = \frac{F}{Bl \sin \theta}$$

$$= \frac{\left(1.47 \times 10^{-1}\ \text{N}\right)}{(0.20\ \text{T})\left(4.0 \times 10^{-1}\ \text{m}\right)(1)}$$

$= 1.8\ \text{A}$

REF: K/U OBJ: 8.3 LOC: EG1.08 KEY: FOP 16.11, p.668
MSC: P

124. ANS:

$$qV = \frac{1}{2} mv^2$$

$$v = \sqrt{\frac{2qV}{m}}$$

$$= \sqrt{\frac{(2)\left(3.2 \times 10^{-19}\ \text{C}\right)\left(1.2 \times 10^{3}\ \text{V}\right)}{6.67 \times 10^{-27}\ \text{kg}}}$$

$$= \sqrt{11.46 \times 10^{10}\ (\text{m/s})^2}$$

$= 3.39 \times 10^{5}\ \text{m/s}$

Then, $F = qvB \sin \theta$

$$= \left(3.2 \times 10^{-19}\ \text{C}\right)\left(3.39 \times 10^{5}\ \text{m/s}\right)(0.25\text{T})(\sin 90°)$$

$= 2.7 \times 10^{-14}\ \text{N}$

REF: K/U OBJ: 8.2 LOC: EG1.08 KEY: FOP 16.11, p.669
MSC: P